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1960-1961

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THE Association was organized in Boston, Mass., on June 21, 1882, with the object of providing its members with means of social intercourse and for the exchange of knowledge pertaining to the construction and management of water works. From an original membership of only TWENTY-SEVEN, its growth has prospered until now it includes the names of over 1000 men. Its membership is divided into six classes, viz.:

A Member shall be an officer or employee of a public or private water works, an engineer, chemist or other person qualified to aid or interested in the advancement of knowledge relative to water works.

An Honorary Member shall be a person of acknowledged eminence in some branch of water supply or of engineering.

A Junior shall be not less than eighteen years nor more than twenty-five years of age, a student or connected with water supply work.

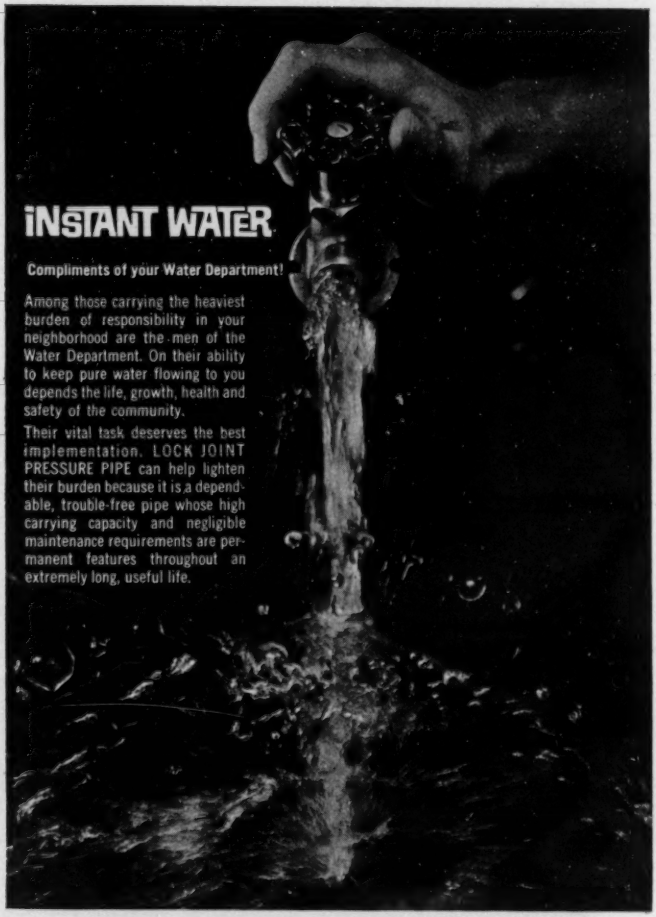
An Associate shall be either a person, firm or corporation engaged in manufacturing or furnishing materials or supplies for the construction or maintenance of water works.

A Corporate Member shall be either a Water Board, Commission, Company or Municipal Corporation.

The initiation fees and annual dues are as follows:

	Initiation Fees	*Annual Dues*
Members	$ 5.00	$ 5.00
Juniors	1.00	2.00
Associates	10.00	25.00
Corporate Members	10.00	15.00

This Association has at least eight regular meetings each year, of which five are held in Boston, one in northern New England, one in southern New England, and one, the annual convention, held in September or October on such date as the Executive Committee may designate.


INSTANT WATER
Compliments of your Water Department!
Among those carrying the heaviest burden of responsibility in your neighborhood are the men of the Water Department. On their ability to keep pure water flowing to you depends the life, growth, health and safety of the community.
Their vital task deserves the best implementation. LOCK JOINT PRESSURE PIPE can help lighten their burden because it is a dependable, trouble-free pipe whose high carrying capacity and negligible maintenance requirements are permanent features throughout an extremely long, useful life.

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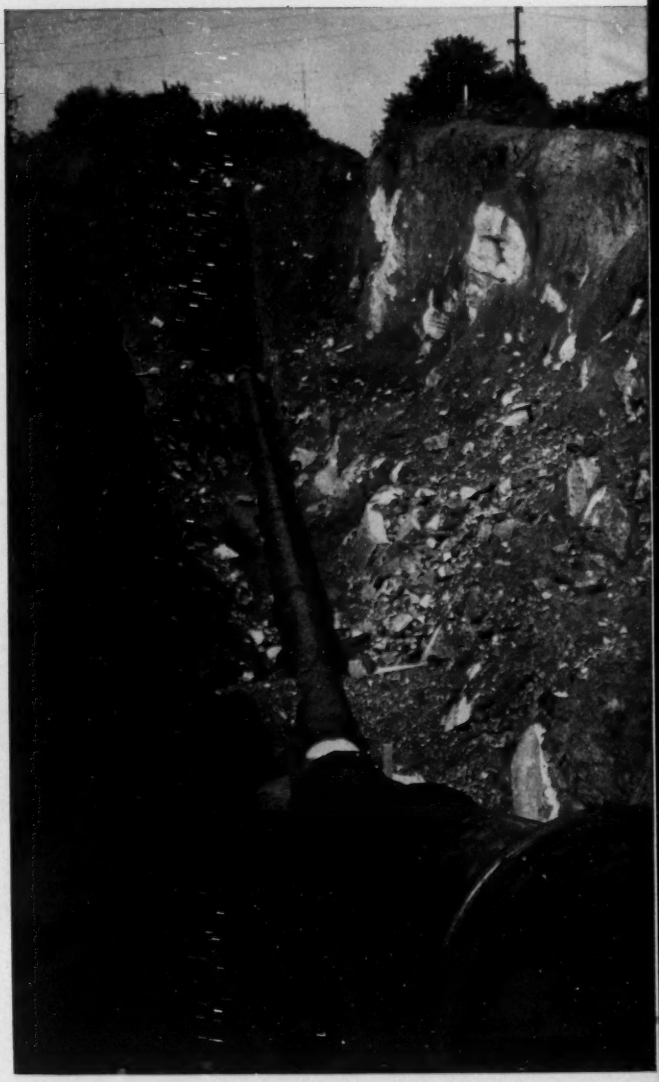

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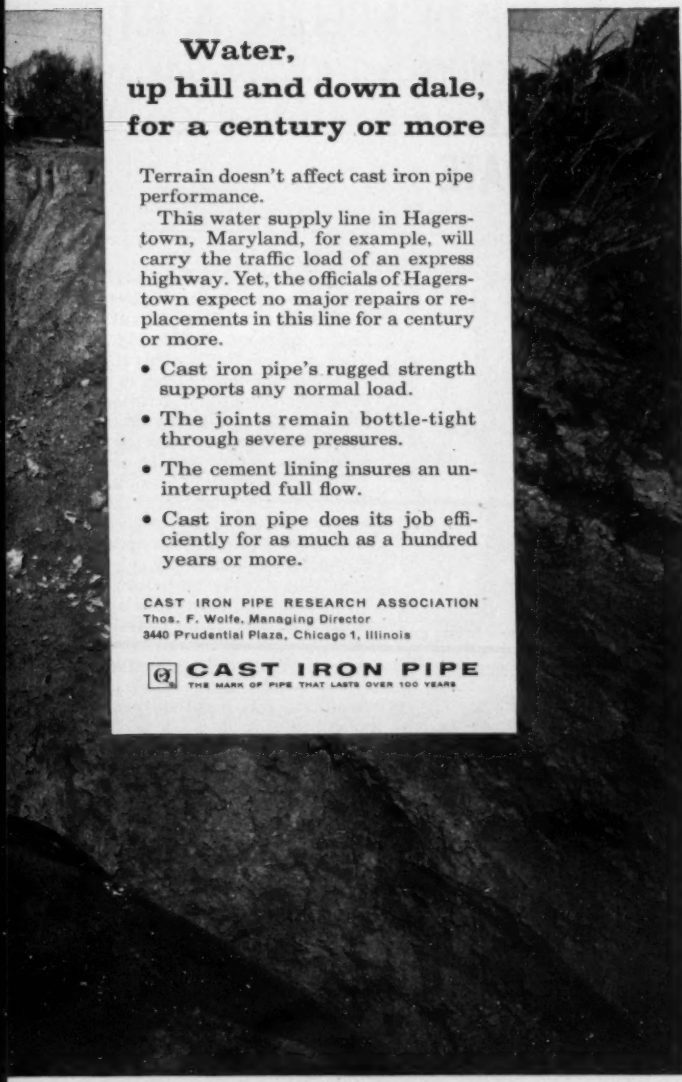

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This water supply line in Hagerstown, Maryland, for example, will carry the traffic load of an express highway. Yet, the officials of Hagerstown expect no major repairs or replacements in this line for a century or more.

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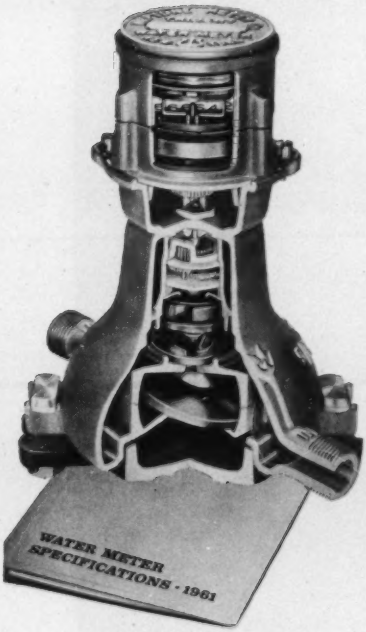
THE MARK OF PIPE THAT LASTS OVER 100 YEARS

are your meter specifications **REALLY UP TO DATE ?**



New Trident Model 60 Water Meter the sealed meter that can be repaired, reset, and calibrated economically in your own shop . . . with complete interchangeability of parts that fit older Tridents and eliminate scrapping major units because of wear in minor parts.

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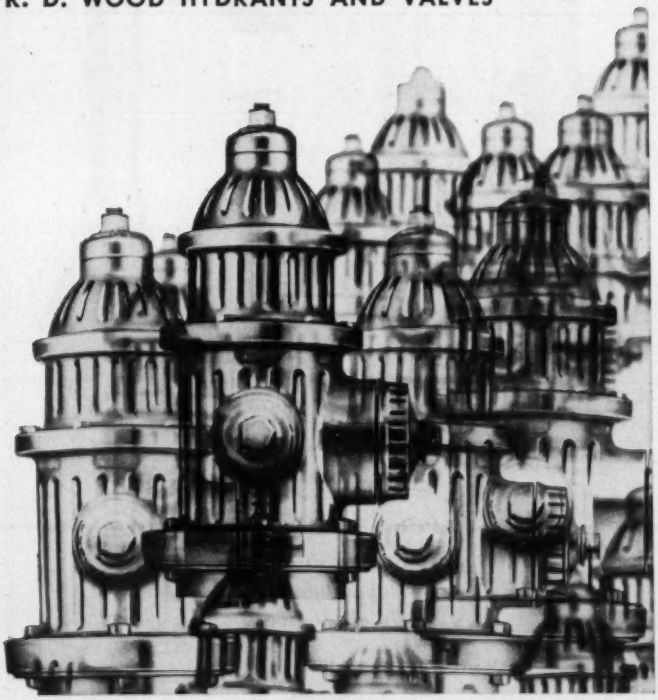

Reasons? Over a million hydrants now in service throughout the world. A number like that speaks for itself, says plenty about the outstanding features of the hydrant and the excellent service and reliability you can expect with R. D. Wood products.

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Heavy Duty
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2 1/2 Inch
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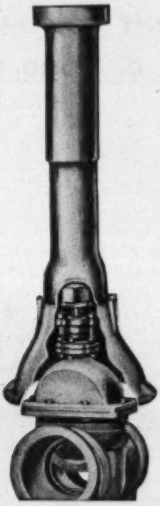

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GENUINE BUFFALO
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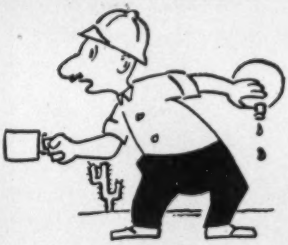
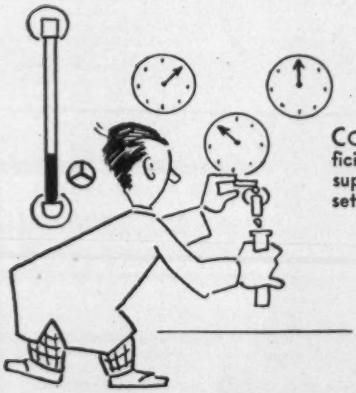
CULPEPER, VA.

TO HELP CONSERVE YOUR WATER SUPPLY



WATER is becoming more scarce, more expensive to obtain, treat, pump and deliver.



CONSERVATION starts with the efficient handling and delivery of water supplies — including meters, meter setting and testing equipment.

THE new Ford Catalog No. 62 is a water man's "bible". It not only pictures and lists the latest in meter servicing equipment, but it contains diagrams and much helpful data for the express purpose of conserving water through more efficient use of meters. It is available on request. Send for your copy today.

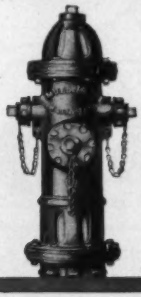
FORD

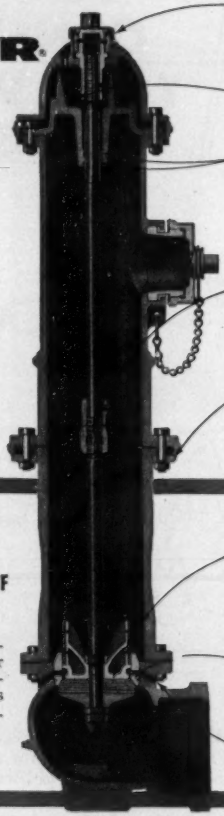
FOR BETTER WATER SERVICES

THE FORD METER BOX COMPANY, INC. Wabash, Indiana

MUELLER

AWWA IMPROVED FIRE HYDRANTS





Bronze Weather Cap—Keeps water away from operating nut; prevents tampering.

Oil Reservoir—Automatically lubricates stem threads, bearing surfaces.

"O" Ring Seals—Threads and bearing surfaces are sealed from water by permanent, watertight, adjustment-free seals.

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Bronze Seat Ring—Straight threads, with copper-asbestos gasket, permits easy removal.

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WEATHERPROOF TAMPERPROOF MAINTENANCE-FREE!

Once set, you can forget about a Mueller Improved Hydrant—the Mueller Hydrant is always ready for action.

Write for information and specifications.

MUELLER CO. 1857 SERVICE QUALITY

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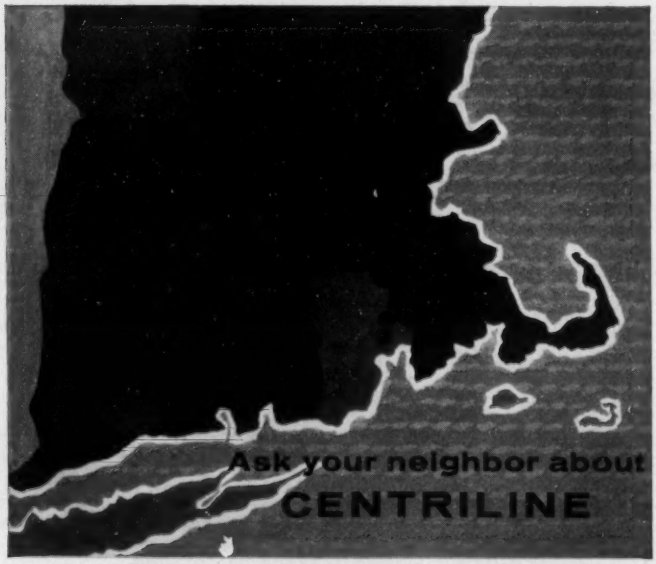
In Canada: Mueller, Limited, Sarnia, Ontario



Spotted on this map are some of the places that have been served by the Centriline Process

Chances are that one of your colleagues has rejuvenated some of his city's piping by Centriline reconditioning. Here's your chance to find out.

Briefly, this process smoothly lines piping—**in place**—with cement-mortar, creating a pipe-within-a-pipe. This vastly increases carrying capacity, stops leakage, prevents corrosion and tuberculation, and prolongs pipe life indefinitely. Pressure goes up, pumping cost goes down, and there's no need to disturb traffic to replace mains. Over 6,000,000 feet of piping, from 4" to 144" diameter, have been treated by Centriline.

ASK YOUR NEIGHBOR

Write today for a list of nearby officials whose cities have cut inconvenience and costs with this pipe-saving process. Hear what they have to say about Centriline. Then write or call us. We'll be glad to show you how Centriline can help **you** solve the problems of pipe reconditioning in place.

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Branch offices in principal cities of the United States, Canada, and Latin America.

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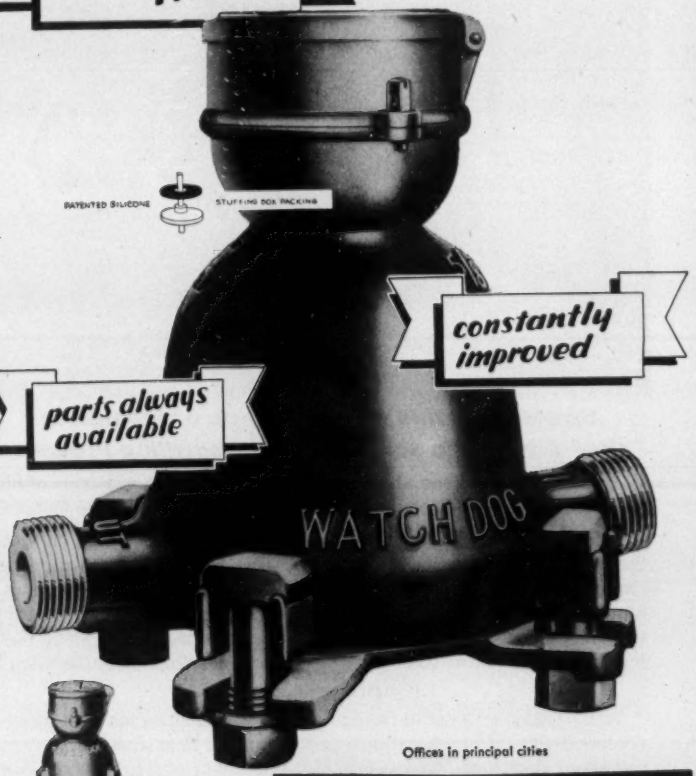

Split case or frost proof

Offices in principal cities

GAMON METER DIVISION

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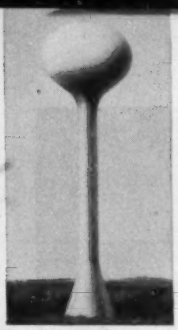
When the look of tomorrow is wanted in the moderate capacity range . . .

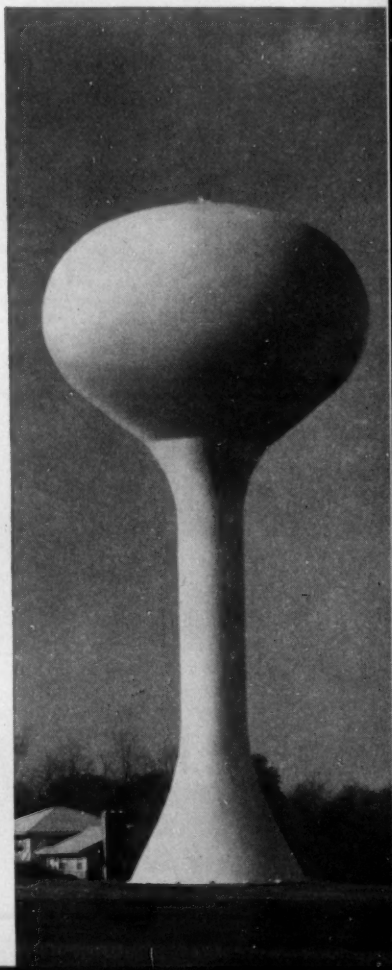
CHOOSE THE PEDESTAL SPHEROID BY PITTSBURGH-DES MOINES



Lansing, Michigan.
250,000 gallons

Humboldt, Iowa.
500,000 gallons

Kingman, Kansas.
500,000 gallons



Annapolis, Maryland.
500,000 gallons

In the evolution of elevated water storage, the PDM Pedestal Spheroid speaks for tomorrow here and now! This smooth and shapely design draws instant attention wherever on view—covers the medium capacity range of 200,000 to 750,000 gallons—and provides the modern-minded community with old-fashioned economy in purchase cost. To find how the PDM Pedestal Spheroid can fit your water service picture, just call in one of our sales engineers. Address our nearest office, without obligation of any kind.

PDM
ELEVATED STEEL TANKS

Pittsburgh-Des Moines Steel Company

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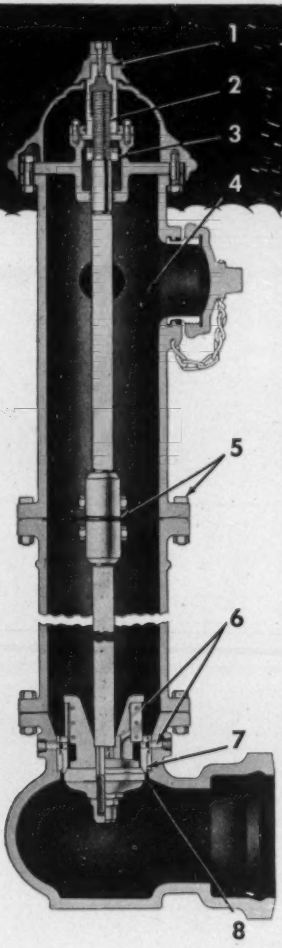

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SMITH MODEL H100 HYDRANT

proudly joins the time-proven Smith product line. No other hydrant has ALL these features:

1. Weatherproof — Tamperproof Operating Nut.
2. Permanently Lubricated Operating Mechanism.
3. Top Travel Stop Nut Prevents Rod Bending.
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6. Multiport Drain Mechanism Operates Automatically.
7. Bronze-to-Bronze Valve Assembly — Self-Sealed "O" Rings.
8. Compression Type Valve Prevents Flooding.

Write for details.

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THE A.P. SMITH MFG CO.

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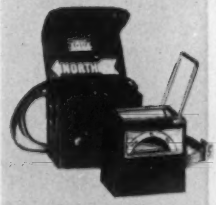

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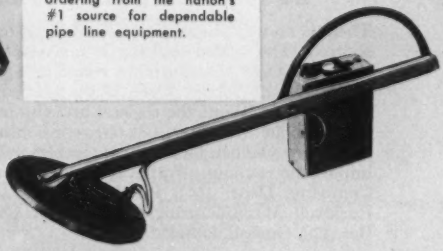
For ordering dependable and proven pipe line equipment, consult your latest Pollard Catalog #27.

Included in the #27 Catalog, and displayed on this page, are the M-Scope Transistorized Combination Leak Detector and Pipe Locator, Audio-Scope, Geophone Leak Detectors, T-10 Electronic Box Locator, Aqua Valve Box Locator and Magnetic Dipping Needles for locating service boxes.

Hundreds of water departments all over the country are using Pollard "one order" service. You, too, can enjoy the advantages of ordering from the nation's #1 source for dependable pipe line equipment.



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JOSEPH G. POLLARD CO., INC.

PIPE LINE EQUIPMENT

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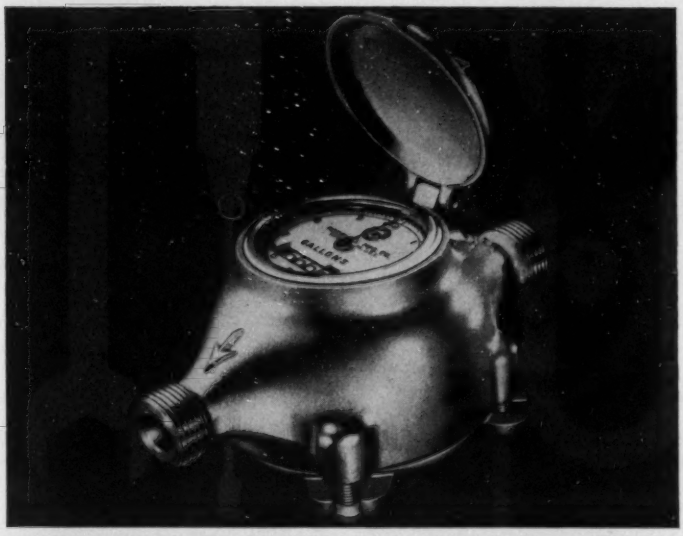

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The only Meter Register that cannot be removed or turned back

There is no way the registration of these meters can be shorted. The sealed register is inaccessible. A metal shield protects the magnetic coupling against all external electric forces. Even if dismantled, the meter won't work without the register and the register won't turn without the meter. Let our representative demonstrate how you can foil meter tamperers and stop losing important revenue. Write Rockwell Manufacturing Company, Dept. 164J, Pittsburgh 8, Pa. In Canada: Rockwell Manufacturing Company of Canada, Ltd., Box 420, Guelph, Ontario.

Imitated but never equalled

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SEALED REGISTER* METERS

another fine product by

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CAST IRON PIPE & FITTINGS

Made in Accordance with Latest Specifications

Including TYTON Joints

Either Cement Lined or Tar Coated

Pipe Made in Everett — Centrifugally Cast in Sand Lined Molds in 16′ L/L

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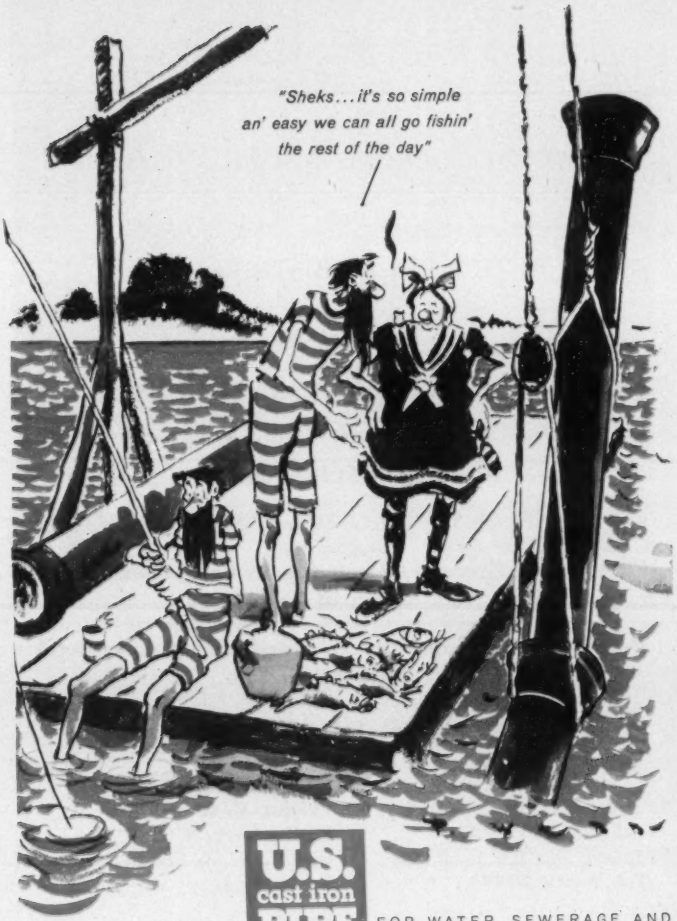

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Easy does it. No bolts, nuts, wrenches. Assembles fast with only a moderate thrust needed to move ball past self-sealing gasket into socket. Retainer ring provides positive lock against pull-out.

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1 Insert the gasket in its seat in the socket. Forming gasket loop helps initial stage of seating. Release of loop allows gasket to spring into the gasket seat where it is securely held.

2 Apply special Usiflex lubricant to the ball and inside surface of seated gasket in socket. After lubrication, ball is ready to be pushed into socket.

3 Ball has been socketed. Retainer ring lugs have been lined up with recesses in bell and retainer ring is ready to be moved into the bell and rotated.

4 After insertion and rotation of retainer ring in bell, the lugs on retainer ring are in back of and in register with internal flange segments in bell. Lead lock is partially inserted into recess between the bell and retainer ring.

5 Lead lock completely inserted in recess is being caulked in place by hammer blows on a wide caulking iron.

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EDDY Fire Hydrant

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- Optional break-flange
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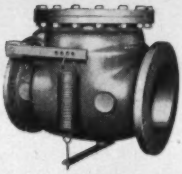

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Completely new designs of horizontal swing check valves are available in sizes from 4 through 12 inches. They operate dependably in either vertical or horizontal positions and incorporate construction features which provide unusual flexibility of operation. These valves may be converted in the field from plain to single- or double-lever operation to meet changing requirements. Other check valves up to 24 inches.

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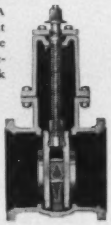
In addition to the regular line of EDDY Taper Seat AWWA gate valves, EDDY now offers a newly designed parallel seat AWWA gate valve in sizes through 12 inches. This valve has been specifically engineered to provide long, trouble-free service. Working parts are designed with heavy, thick section and large seating surfaces for dependable operation and improved wearing qualities. The valve has two-point, free-floating wedging for minimum friction and maximum operating ease. Other AWWA gate valves are available through 48 inches.



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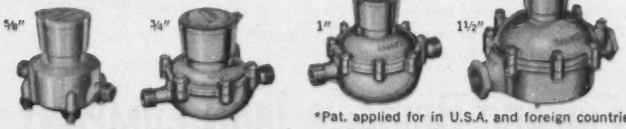

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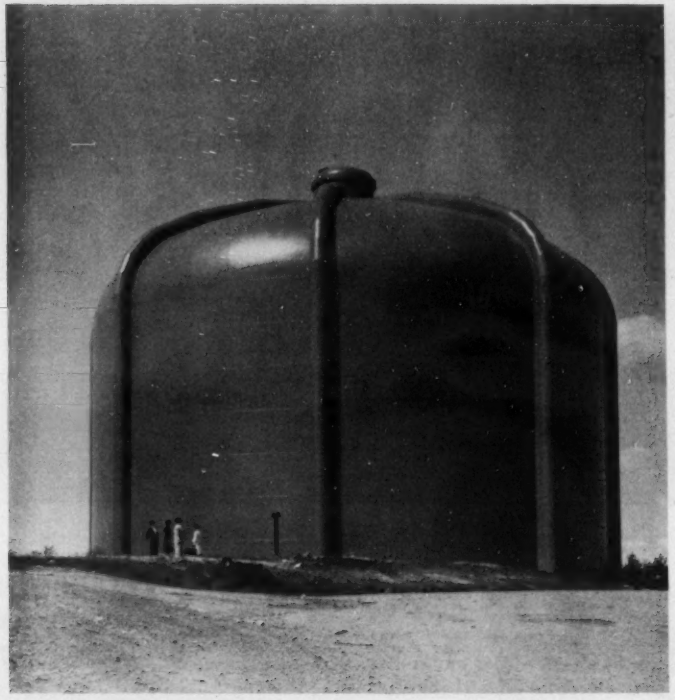

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WATER QUALITY MANAGEMENT OF THE FUTURE

BY JOSEPH E. FLANAGAN, JR.*

[*Read September 21, 1960.*]

Whenever many of us in the field of public health think of the northeastern section of the United States, and specifically of the New England States, we are inclined to remember that this part of the country was and still is the home of much original and independent thought. This is exemplified by its pioneering in public health, by the continuous and successful development of its large educational institutions and by a characteristic independence in thought and action. A number of years ago, the term "Yankee ingenuity" was a common one in this section of the world. It was adopted by Worcester Polytechnic Institute in its "Yankee Ingenuity Scholarship." This unique grant is given annually to a high school student who has shown a consistent interest in science and has been able to develop and operate a mechanical device demonstrating a scientific principle. All of us owe a great deal to New England.

New England remains one of the major industrial centers of the country, even though much of its early industry has vanished. Newer and different industry has developed, and in the last 20 years the area has had a great increase in use of its natural resources for both industry and recreation. Water is not the least important of these resources.

The recent hearings before the Select Committee on National resources of the United States Senate contain interesting reference to water quality management. In particular, there is the statement by the Hon. John F. Kennedy, Senator from Massachusetts, on the need for increased attention to the problem of water pollution. Senator Kennedy's statement reads, in

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part, as follows: "We must pay increased attention to the problem of water pollution. The availability of clean water is of importance not only to our health and living standards, but to our industrial development as well. The early growth of New England was possible because there was plenty of good water available. Today pollution is the largest single destroyer of New England water resources, hindering the economic health and prosperity of the region." Senator Kennedy included this comment as one of five principles which he believes should be embodied in a water resources program.

At other points in the hearings, the matter of recreational use of water in New England was discussed. The hearings represent a good cross-section of thought on water resources problems of New England, and to some degree, cover many of the problems faced by other areas of the United States. Many of us hope that the traditional and effective "Yankee ingenuity" will help New England and all Regions to solve the difficult problems of water quality management of the present and the future.

The foresightedness of New England in developing protected watersheds for its municipal water supplies has long been recognized. Certainly it stands her in good stead now. But as the pressure for recreational use of water increases, the Nation finds itself moving away from completely protected watersheds. More and more frequently water-supply impoundments are being opened to recreational use. Concurrently, water treatment is increased as necessary. As New England searches for new economic bases to replace diminished ones, its attractiveness as a vacation land emerges with new importance. It appears now that New England will move rapidly toward recapturing the attractiveness and advantage of once undefiled surface waters. A sound plan and system for water quality management is essential to reach this objective.

Today water quality management in its broader sense is discussed in terms of the future, for it is still more a concept than a practice. The development of it as a practice is a major need and a major challenge of the next decade.

As I view it, water quality management of surface waters —and I will limit considerations here to surface waters—is a system for providing the right water quality at the right place.

It embodies a set of procedures for keeping each segment of the surface water resource in the continuous dynamic balance necessary to meet the requirements of each significant use and next use. The concept may be considered quite simple, but the development of it in a form practical for application is definitely not simple.

The critical importance of water quality management stems, of course, from the great expanding demand for water against an essentially fixed supply. Only one-fourth of the average annual runoff, or about 314 billion gallons per day, is considered to be available at this time as dependable surface supply (1). The remaining three-fourths of runoff is in the familiar "wrong in time or place" category.

Depending on who is gazing into the crystal ball, this 314 BGD of water appears to be inadequate or more inadequate to meet future demands. If the hydrologists who estimate that about half of total runoff ultimately can be captured for use are correct, then we can look forward to a surface supply from this source of about 635 BGD. Augmentation further is possible in a number of ways: (1) through intelligent development of the great underground water reservoirs, (2) through desalination of ocean and brackish waters, (3) through reduction of evaporation, and (4) through weather modification. There are so many imponderables associated with these possibilities that predictions of their contributions to dependable supply are almost impossible. We can assume that they will provide some supplementation of the normal surface supply, but the amount and broad geographic availability of these supplies will not be such as to alter appreciably the national water picture.

Projections of water use over the next decade or two seem to be generally accepted—the figure of 600 BGD for 1980, for example. Less reliable are the projections for the ensuing two decades, and such estimates as 1000 BGD by the year 2000 may be considered "best guesses."

As pointed out by the Senate Select Committee on National Water Resources (2), "it would appear on the surface that by the year 2000, total water use could exceed the limits of the Nation's developable fresh water supply resources." Counter to this view, they say, "this would not, in fact, be the case, how-

ever, because all of the various demands for water cannot simply be added together . . . ." The Committee Report goes on to point out that "water is used many times over" . . . and that "the total of various purposes which can be served by a given quantity of water will vary from river basin to river basin . . . ."

The Senate report makes the point I wish to emphasize: "Water is used many times over." It will be necessary increasingly to re-use water, and the extent and type of re-use will vary from place to place and time to time. Whether the re-use be two, four, or six times, water quality management will be the key to meeting supply needs thereby. And the scientific basis of such water quality management is ability to measure substances in water, to understand their behavior in water, and to remove or avoid them economically when necessary.

I would like to turn now to some of the considerations of importance in water quality management of surface streams. From upland source to the ocean the stream is subject to series of both withdrawals for use and contributions from tributaries and underground supplies. Because some withdrawals involve consumption loss, the stream flow is reduced. Other withdrawals are almost completely returned, some slightly impaired in quality, some highly impaired and many in a condition between these extremes. Many uses and values of the stream do not involve withdrawal at all—the propagation of fish and wildlife, the recreational and aesthetic uses—and many other values are in the stream itself. Furthermore, these uses and values are not inconsequential. The views of Irving Fox in "Water—Supply, Demand and the Law" (3) are of interest here with respect to what he considers to be "the most arresting feature of the water supply-demand outlook, both East and West. It is the rapid increase in water use for recreation purposes and a growing recognition of the importance of preserving the aesthetic characteristics of the Nation's water resources. Since World War II, while the national economy has been growing at a rate of about 4 per cent a year, recreation use of water areas has been increasing at a much faster pace. For example, during this period, use of T.V.A. reservoirs increased at a rate of 15 per cent per year, while use of the reservoirs of the Corps of Engineers increased at a rate of 28 per cent per year. All signs now point to a

tremendous increase in recreation water use during the next two decades. Since we now have about 20 million fishermen and approximately 5 million outboard motors, there can be no doubt about the economic importance of water-based recreation activity.

"But of even more significance than the economic activity which stems from recreation is the importance of outdoor play and relaxation to our highly urban and industrialized society. Yet the demand for clean waters is not related entirely to recreation. As forests and fields give way to factories, houses, and highways, and as areas become more densely populated, it is increasingly important for lakes and streams to be aesthetically pleasing. As our society becomes more prosperous, as well as more densely populated, I anticipate a wide-spread insistent demand that the intrinsic beauty of the Nation's water resources be maintained."

The point of view expressed by Fox illustrates the wide range of quality control that we may be called upon to provide in the future. To date we have been more concerned with abating the inexcusably serious pollution conditions than with preserving clean waters. In the future it will be important to give more balanced attention to the total job of keeping water clean. The old adage of "an ounce of prevention . . ." warrants serious attention. It should be more efficient and economical to plan water use to prevent impairment of the resource than to let use proceed uncontrolled and then try to correct the impairment.

Assuming that planned water use will be the order of the future, what do we need to know to control quality? First, of course, we must be able to measure pollution qualitatively and quantitatively. Analytical methodology is the first requisite to quality management. A water quality symposium held recently in Cincinnati reflected the present state of the art and science of water quality measurement. It showed that our present techniques are inadequate for current problems, to say nothing of future ones. It demonstrated, I believe, a need for methods and devices at least an order of magnitude better than today's for problems of the next decade. As the number of substances in water increases, we shall have to be more discriminating in what we measure. Each parameter, old or new, should be critically

evaluated so that the corresponding measurements will be most meaningful.

A further understanding of physical, chemical and biological forces and their interplay in the aquatic environment is fundamental to effective water quality management.

Physical factors have not received appropriate attention from water quality scientists. As points of discharge and withdrawal are located closer and closer together, dispersion, turbulence, stratification, wind action and related factors will need more precise delineation from the standpoint of understanding, predicting and monitoring what takes place, and of designing better outfall and intake structures.

Certainly hydrodynamics will need more attention and application in the future. Sedimentation and transport of silts and other suspended matter have received much study and have been taken into account in the design of drainage, treatment and river structures. In spite of this, control of silts and debris has not been optimum. Most of us have seen streams of silt from construction sites, mining and agricultural operations, and trails of debris from timbering and related activities and certain industrial operations. More ingenuity than we have applied in the past will be required for reduction of these impacts on our water resource. On the credit side of the ledger the progress made by the soil conservationists by erosion control and other means is especially worthy of commendation.

Temperature will be more significant in the future. Power growth predictions point to added problems of thermal pollution. It will be a task of water quality management to develop the knowledge necessary to predict whether a given rise in temperature will promote or retard stream purification processes for wastes of varying character; what the effects on fish and related aquatic life will be; what the effect on growth of slimes and weeds will be. More reliable methods of forecasting the rate of heat loss under varying meteorological and hydrologic conditions will be needed.

More complicated than the physical are the chemical and biological aspects of water quality. We live in a chemical age, and its almost endless permutations and combinations are reflected in the water environment that receives its wastes. Separa-

tion and identification techniques and instrumentation are in only the primary stage. Our understanding is meager of the reaction kinetics of organic chemicals in dilute aqueous solution. Biochemical phenomena are reasonably understood only for the more sewage-like substances. Protracted or long-range physiological effects of newer chemicals on man are hardly understood at all; the shorter term effects on aquatic life are almost as unknown, but we can assay lethality grossly. Here the need is obvious for more sensitive, quicker and less costly physiological assessment methods relating to both human and aquatic life.

Our understanding of biological operations in the water environment is mostly qualitative. It needs to move in the direction of quantitative understanding if biological measurements are to be incorporated in the system-analysis matrix that will make possible tomorrow's water quality management.

A third major element of significance in water quality management is water cleaning technology. This includes the characterization of wastes, their removal or treatment, and the monitoring of effluents. Determination of the pollutional characteristics of wastes involves procedures for measuring their amenability to aerobic and anaerobic treatment, their fate in streams, their effect on the streams and stream life, their effect on and removal by water treatment processes and their effect on humans, plants and animals. Suggested characterizations of wastes have been in the literature for several years, but their general acceptance and use have lagged.

Likewise, the development of new treatment methods has lagged. Our water treatment methods are inadequate for the vigorous cleaning of waters likely to be required in the next 10 or 20 years. The most difficult problem appears to center around the removal of ions and molecules, particularly those of synthetic organic chemicals. This area of research demands much more attention than it is receiving now, for it is prerequisite to the successful reclamation and re-use of water needed in the future.

Up to now we have relied on the treatment capacity of receiving waters in greater or lesser degree. Probably we cannot depend on using much of that assimilative capacity for the treatment of municipal and industrial wastes. Increasingly it will be

required to accommodate that pollution from land use which is beyond sewerage and practice control: pesticide and other commercial poison residues, natural and applied soil nutrients, eroded materials, and return irrigation contributions. Even with the most refined treatment of municipal and industrial wastes, we may be fortunate if any assimilative capacity of receiving streams is available as a safety factor. The significance of more advanced methods of waste treatment thus looms larger and larger. Better measurement tools to monitor residuals reaching our water courses will be more important, as water quality balances become more delicate.

In order to "transistorize" the maze of scientific knowledge, which we hope to acquire, into its applied form—wisdom—we may need to reduce to a common discipline the various scientific languages of the physical, chemical and biological water worlds. Mathematics seems best suited to this purpose.

The first step then is to convert physical and biological knowledge to appropriate and workable mathematical expressions. This is, of course, not always easy to do in precise terms, especially for biological events. The limitations of mathematical expressions of biochemical oxygen demand and oxygen sag are familiar examples of the difficulty. The next step is to develop a mathematical matrix or model into which multiple variables can be fitted. Finally, systems analysis techniques are applied to solve problems presented to the system. The whole process is one of accounting. It may be likened to a system of dynamic accounting where deposits, withdrawals, fluctuating values of assets, varying rates of simple and compound interest, and actuarial events are expressed continuously in terms of running balances and other management expressions essential to assessing and guiding an enterprise. It is somewhat in this fashion that I visualize the art and practice of effective water quality management emerging.

The resources behind the scene will be scientific staff, laboratories, instrumentation, basic data, measurement techniques, computer technology, and theoretical and applied mathematics. On the stage will be all of the competing and conflicting economic, political, social, legal, administrative and technical actors. In the audience are the critics, professional and lay, the

jury, the public—striving to make sense out of the chaos, trying to separate fact from emotion, trying to separate basic issues from selfish interest, trying to identify the principles that can serve as firm foundation for law and practice.

The future significance of water quality is perhaps too obvious to belabor. We need it in developed form now in several areas of the country. As the water quantity squeeze becomes tighter and allocation doctrine and law are reshaped, re-use will increase, and water quality control will assume greater if not critical importance.

The potential for development of water quality management practice is hinted in the extensive treatise on "Technology in American Water Development," published for Resources of the Future. With reference to conservation and quality control the authors say, "Water quality control has not received the comprehensive attention technically possible. No administrative machinery has been in motion which examines all aspects of water quality on a basic wide scale, and applies measures of quality control, including paired use plans, on a unified basis to the watershed."

This commentary has all the flavor of an invitation for some one to fill the vacuum. As we look at reasons why no one has moved more aggressively to do so, we can see some of the same complications that may be responsible for unsuccessful efforts to develop national water policy. Aside from the lack of scientific knowledge there are so many interests, aspects and agencies involved that no one has been confident enough to take the lead or move alone.

We see constant reference to the inseparability of water management from soil and forest management. Yet something must come first, and there must be some place we can start on this most complex problem of developing the practice of water quality management. If we believe that good water is essential to national survival, that it is a "priceless" commodity, that it is the most critical factor affecting our economic development, then perhaps we must approach policy and practice development with the view that water quality objectives should be established first, and that water and land uses must be adjusted to fit these objectives.

Here again we will probably have to learn to walk before we run. The local setting offers a good place to begin. Starting with smaller and simpler river-basin systems, we can inventory existing hydrologic, use and quality factors and attempt to set these in a framework or system for analysis. We can then challenge the system with hypothetical or predictable conditions of supply, demand, use, and re-use, and attempt to determine quality at points of significance in this dynamic system. As we acquire experience with simpler systems and identify and formulate the more critical variables, we can move on to more complex systems, until we develop a methodology sophisticated enough to accommodate all the significant water quality management problems we expect to encounter in the future. This is a technical challenge of high order and one to which all of us are called to respond.

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WATER-BORNE DISEASES

BY JAMES C. HART, M.D.*

[*Read December 15, 1960.*]

Water is a prime necessity of life. It is an essential article of diet, a prerequisite for proper cleanliness of person and clothing, and indispensable in manufacturing processes, for the conveyance of wastes and for protection against damage from fire. A supply of pure water is an important factor in determining the location of populations and in fact the degree of advancement of civilization.

It is surprising that people did not realize until a little over 100 years ago that water could be the transmitting vehicle of the causative agents of sickness and death. Starting with the noteworthy discovery of Snow in 1854 that a polluted well was the cause of an epidemic of cholera in London (1), it has been demonstrated over the years that typhoid, dysentery and other intestinal diseases were spread through water.

In addition to the demonstration of specific diseases spread through water, purification of the public water supplies caused a remarkable decrease in the general death rate in municipalities (2). One of the first to prove this was Hiram F. Mills, a member of the State Board of Health of Massachusetts, who noted in September, 1893, that there was a general decrease in mortality following the filtration of water supply at Lawrence, Massachusetts. About the same time Dr. J. J. Reincke, Health Officer of Hamburg, Germany, observed the same phenomenon in his city. In 1904 a sanitary engineer, Allen Hazen, was able to calculate that where one death from typhoid fever had been avoided by the use of better water, two or three deaths from other causes had also been prevented. This improvement of general health following the purification of water supplies is comparable to our observations of freedom of excess mortality in the absence of epidemics of respiratory diseases such as influenza. When an epidemic of influenza occurs we find that there is a general increase in the death rate from heart disease or some

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other condition not thought to be related to influenza. As a consequence one of our ways of detecting epidemics of influenza is to keep track of the total deaths in our cities as recorded week by week. A sudden large increase usually points to an epidemic of influenza. However, an epidemic caused by contaminated water supply might show the same phenomenon.

In the March, 1960, World Health Organization Chronicle (3) is summarized an objective study by Dr. Abel Wolman of water-supply problems in 17 Latin American countries. In this article Dr. Wolman points out the importance of good water supplies in the prevention of deaths from diarrheal diseases. "It is clear that mortality in early infancy is excessive. For children aged from 1 to 4 years, diarrhoeal diseases represent the main cause of death in 12 out of 17 countries. In the others, the diarrhoeal diseases figure among the five main causes of death. The rates of mortality from typhoid, gastritis, enteritis, etc., are very high in many of these countries. In general, it appears that a reduction of from 30% to 60% in diarrhoeal diseases may be expected if drinking water is supplied in an accessible form and in adequate amounts. The high mortality from these diseases is but one of the many consequences of lack of water supply."

This statement describes conditions today and not a hundred years ago.

Cholera

Cholera, which was the first disease shown to be waterborne, is still widely prevalent in certain sections of the world, although fortunately not in the United States at the present time. Only this week I received a notice of a four-day International Conference on Cholera, to be held in East Pakistan where a new laboratory is being set up to study the disease. The United States is spending $400,000 to maintain this laboratory for the control of this single disease. Although we are free of cholera in the United States today, we know that we are less than 24 hours by air from these infected countries.

Typhoid

In 1900 typhoid fever was the fourth leading communicable disease causing death. Ordinarily the germs are spread from one person to another through handling food or drink for other

people. When there is fecal contamination of water, milk or food by a typhoid carrier or case and there is inadequate treatment before use, outbreaks of the disease will occur. Large epidemics of typhoid fever (4) have taken place as recently as the 1920's. In 1926 there was an outbreak in Hanover, Germany, with 22,423 cases. In 1929 in Lyons, France, there were 2100 cases. In 1956 at a camp meeting in Monarch Springs, Missouri (5), there were 34 cases out of a group of 550 people. Two thirds of these people suffered from diarrheal symptoms and it was found that the well had become contaminated from a nearby cesspool.

One of the interesting things about water-borne typhoid fever is that the typhoid germs seem to live longer in the water supply when the water is cold. Rarely has an epidemic of typhoid been reported in the summertime. It is usually in the late fall, winter or early spring. The same is true of other bacterial intestinal diseases.

At your September meeting in Montreal you heard a report of an outbreak of 14 cases of typhoid in Keene, New Hampshire, which began in November, 1959 (6). These cases apparently occurred after cleaning the sand filtration bed. A typhoid carrier was discovered in the camp on one of the watershed ponds. It is fortunate that many more cases did not occur.

Gastroenteritis

The most common type of illness which occurs when water supplies are contaminated is gastroenteritis. Outbreaks of this type of illness have been reported over the years. One of the largest such instances occurred in Rochester, New York, in 1940, when an employee of the water company accidentally left a valve open in a cross connection between a polluted fire-protection system and potable water (7). Over 35,000 cases of illness were reported, among which were six cases of typhoid fever. Over 100,000 cases of gastroenteritis were reported from water-borne outbreaks in the United States from 1938 to 1945.

Bacillary Dysentery

Bacillary dysentery has been frequently reported as spread through water. In the April, 1960, issue of "Health News,"

published by the New York State Department of Health (8), there is an excellent report of a water-borne outbreak of dysentery which occurred in January, 1960, in two small villages in Albany County. Over 1400 cases of illness were reported in a population of 3200. To explain the outbreak, it is believed that the water was heavily polluted with dysentery bacilli, and at the same time a breakdown of the treatment took place. There was a period, from hours to a day or more, when no chlorine and possibly no alum were added to the raw water as it passed through the plant. Even though the water passed through filter beds, the pollution was so heavy that filtration alone was not sufficient to make the water safe for human consumption.

Amebiasis

Outbreaks of amebiasis or amebic dysentery of water-borne origin have also been reported on occasion. The first-known such incident occurred in 1933 when the water supplies in two hotels in Chicago became contaminated with sewage (9). Hundreds of persons visiting Chicago to see the World's Fair became infected, with resulting illness and death for many. These visitors in turn spread the infection all over the country. A large outbreak (10), reported in South Bend, Indiana, in 1952-53 resulted in infection of 50% of the employees of a plant where 1500 people worked. There were 31 clinical cases and four deaths. Here again it was attributed to contamination with sewage of the distribution system through a faulty suction line. The hazard from amebiasis is a cause for concern, since a high percentage (as much as 25%) of people coming from tropical or semi-tropical areas is known to be carriers of the amebae. Protection of watershed areas is important, since standard chlorination treatment does not kill amebic cysts.

Virus Infections

At one time it was thought that poliomyelitis might be spread through water supplies, but there are no confirming reports, although it is known that the polio virus lives in great numbers in the intestinal tract of patients and carriers.

Another intestinal viral infection which is known to spread through water is infectious hepatitis. A physician from the Public

Health Service has recently summarized water-borne outbreaks of infectious hepatitis and has listed 28 such epidemics (11). One of the interesting aspects of this is that although wells are a source of water in most of the reports, at least six municipal water supplies have been incriminated as the source of the epidemics. Likewise it is important to note that 6 of the 28 outbreaks occurred in the United States. The largest outbreak occurred in Delhi, India, in 1956 when over 28,000 persons became ill with jaundice (12). "In this instance, . . . the water supply became contaminated with sewage, through an accidental shift in the course of a neighboring river. An alert sanitary engineer immediately increased the chlorine concentration in the city water supply, and no noticeable increase in the rate of cases of acute gastroenteritis was recorded. However, a month later the hepatitis epidemic began. The increased concentration of chlorine had apparently been effective in destroying bacterial pathogenic agents, but hepatitis virus had slipped through."

Connecticut Outbreak

This past summer in Connecticut we experienced an outbreak of infectious hepatitis which involved 20 cases (13) among children attending a rural school. The common denominator of the 20 cases was the water supply to the upper grades. All epidemic cases occurred in the pupils who drank water from the new section with its own well. At the present time pupils are using bottled spring water until a new well can be built.

Conclusion

We must recognize that the threat of water-borne intestinal disease is still present. The occurrence of outbreaks of typhoid, dysentery and hepatitis through the medium of water within 150 miles of Boston during the past year or so should make us keep alert to the danger. There is necessity for strict watershed control and provision for adequate treatment. Recreational or other use of watershed areas is a potential hazard of varying degree. Such use of water bodies as a source of water must be classed as unsafe practice.

It is not only necessary to improve our engineering and laboratory controls, but we must also overcome our human frailties

and our tendency to make mistakes—our failure to recognize a dangerous situation and act immediately. This requires individuals with a sense of responsibility, who are devoted to their work and community. I know the New England Water Works Association and its members are dedicated to this purpose.

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THE CHALLENGE OF THE SIXTIES TO THE WATER UTILITY OFFICE

BY RICHARD G. SMALL*

[*Read January 19, 1961.*]

In a recent Gallup Poll of voters' wants from the new administration in Washington, 63% of those questioned listed first their wish for Congress and the new President to "hold down prices and prevent inflation."

Most economists are of the opinion that the great post-war boom, with its may excesses, is ending; and that following this brief lull, the economy will surge ahead, not from the effects of the War, but from the effects of a vital and free economy.

Things will be different under this new surge and the attitude reflected by the Gallup Poll and business men gives some advance warnings. Slogans are beginning to appear like "Job Security Through Cost Control."

What do these indications mean to a water utility management? Certainly, for one thing, it means that with the community becoming more price-minded, water utility management will find it increasingly difficult to get increased rates either through utility commissions or accepted by the consumer—even though water absorbs a small fraction of the consumer's dollar.

In a recent house building magazine appeared the statement, "It's ten times easier to save a dollar than it is to earn one." Since most water utilities experience a far lower net profit than 10%, it becomes many times easier to save a dollar in the water utility industry than to earn one.

This, I believe, is the great challenge to the water utility office of the 60's: to so develop the art of record keeping, interpreting, and reporting that management will be assisted to the fullest toward the goal of better service at lower cost.

I am sure that we all recognize the great benefits derived from competition. You have only to hear a group of businessmen talking a short time when you realize what force is exercised by

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the consumer having a choice of sellers from which to purchase. And certainly it may be agreed at least among us capitalists, that our society has more goods and services at less cost than it would otherwise have without competition.

However, in the public utility industries there is lacking the regulating force of competition. In its absence, the consumer depends upon two forces for protection:

1. Public utility regulation.
2. Professionalism of management.

The first semblance of government regulation came before 1850 in the form of laws regulating rates and use of streets. State commissions began to appear about 1870. The Interstate Commerce Commission was formed in 1887 to regulate interstate railroad transportation.

The legal justification for regulation is based on the old Anglo-Saxon laws defining certain activities as "public callings," or businesses "affected with a public interest," such as inkeepers and carriers. Such laws resulted from injustices inflicted on the public. And from the many decisions, one can follow the evolving philosophy which contains the basic requirements to the successful operation of a public utility.

The first requirement of a utility is to serve as many applicants as capacity will allow and for which the customers are willing to pay. Little regulation is required to enforce this. Other requirements, resulting in considerable regulation, are as follows:

I Reasonably adequate service,
II Reasonably priced service, and
III Service without discrimination.

Regulatory bodies have, in the main, been most active in the field of rates, endeavoring to approve of rates which allow for the development and maintenance of a healthy financial structure.

Of the future of regulation, it can be forecasted for a certainty that as the science of regulatory control increases and the legislative bodies become more responsive to the demands of the voters, a greater demand for disclosure of utility operations will result.

This brings us to the second force upon which the consumer must depend, namely, the professionalism of management. It is the management which exercises the direct control over salaries and wages, materials, and related operating costs.

There are at least four elements to the definition of a profession:

I Special training recognized by universities and colleges,
II Consisting mainly of mental, rather than manual or artistic labor and skill,
III Recognition of responsibility to the public service, and
IV A code of ethics generally accepted as binding upon its members.

Thus, to the management of the water utility office of the 60's falls the increased responsibility to do the following:

Improve its knowledge,

Use greater imagination and creativeness in the utilization of men, machines, materials and methods (the four M's in office management).

Engender greater zeal and enthusiasm in the analysis and study of cost areas and thereby contribute to more efficient operation.

Press for greater communication of ideas and procedures in the industry.

The Latin root word for "audit" is "audire," meaning to hear. The beginning of an audit cycle consists of hearing and studying to become acquainted with the area under audit. This is followed up with testing, appraisal and recommendations. To function properly as the "eyes and ears" of management, the office manager must apply the "audit cycle" to each area of responsibility within the office first. This is important because it is necessary to put the office "house in order" so that the greatest benefits may be achieved by the application of the "audit cycle" to other parts of the organization.

The first area to consider is personnel. It is certainly a major cost area in the office According to the National Office Management Association which conducts an extensive annual salary survey, office salaries have increased from an average of $44.00 a week in 1950 to $71.00 in 1960, an increase of 61%. Rising costs are only one side of the picture, however.

The U.S. Secretary of Labor issued a pamphlet last year, called "Manpower—Challenge of the 1960's." One of the pro-

jections shows a 25% increase in job opportunities for clerical workers. The water utility office will be competing with many other offices to get workers.

By 1970, it is forecasted that there will be a 20% increase in the work force to 87 million, and one-third (29 million) of the entire work force of 1970 will have come into the labor market in one 10-year period. Some 15¼ million will leave the labor force before 1970, due to death, retirement, marriage, childbearing, etc.

The facts indicate further that the new recruits of the 60's will predominantly come from young workers under 25 and people over 44.

These facts would seem to indicate that while wage costs increase, the office manager may not get the type personnel he most wants. This means that he should audit his personnel to insure that he is getting the maximum returns.

An audit of personnel may be used to appraise the effectiveness and efficiency of operation. It covers the following areas which, of course, is not a complete list, but only representative of the type of content:

1. Organizational chart
2. Management's personnel policies
3. Personnel data on sex, race, age, kind of work, tenure, etc.
4. Wage policies and structure
5. Methods of communication between employer and employees
6. Personnel procurement policies
7. Personnel records
8. Job analysis, specifically duties, responsibilities, and job requirements
9. Labor turnover study.

As attention is given to these areas, problem areas will be more easily dealt with.

The second most important area to audit is methods. This step is fundamental before any consideration is given to machines, for as so often is the case, if methods are streamlined, any consideration of machines is materially altered.

Tools of method study are: *work distribution chart*, which is a detailed analysis of the work requirements of a department; *flow process charts*, which reveal the steps to accomplish one activity of a department; *time analysis*, which gives the schedul-

ing and processing time; and a *job analysis*, which identifies and describes the job and states the requirements of the worker.

Terry (Office Management and Control) itemizes these important advantages of sound office procedures:

> "1. *Delay and waste in time are minimized.* The successive steps are predetermined and known. Hence, delays are reduced in deciding what to do next, and hesitations are avoided.
>
> "2. *Uniformity of action is obtained.* Common clerical tasks are handled in an identical manner each time they occur. Work can be easily located and quick checks on progress can be made. Standardized forms, work habits, and controls can be utilized.
>
> "3. *Savings in cost* of office operations are usually realized. Procedures help to keep the work moving, to guide employees in their respective tasks, and to eliminate unnecessary steps.
>
> "4. *Fixed responsibility* for work can be attained. The use of procedures divides the work operation so that definite office tasks can be assigned to an individual or to a certain group of employees who can be made strictly accountable for carrying out the work. There is no guessing as to who is answerable for the performance of the work.
>
> "5. *The work of training personnel is simplified.* The duties and operations in each job are clearly defined. Information is known regarding what the employee must be capable of doing. Selective training programs can be focused on the particular requirements needed by the employee.
>
> "6. The chances for *errors are reduced.* Procedures formalize the successive clerical steps, and an omission of any of them is unusual. Furthermore, the possibility of an inaccuracy in the work at any one point is minimized, since the employee becomes particularly efficient and adept at his operation because of specialization and repetition.
>
> "7. The *service of the office is improved.* It is by means of procedures that the modern office is able to meet the large demands placed upon it. Getting the work out, on time and in acceptable form, is possible through the help of office procedures. They make it possible to render the type of office service desired."

Very closely related to the methods study are the supplies and stationery.

One objective of an audit of supplies is standardization. Downs, N.A.A. Bulletin, vol. 34, concludes that:

> "The more that forms, letterheads, envelopes, typewriter ribbons, carbon paper, stencils, machine tapes, pencils, etc., can be standardized, the greater will be the opportunity for economy. In addition, there are numerous advantages to standardization. Fewer items are

ordered; a reduced number of purchase orders need to be processed; there is better control of stock; and less storage space is required."

Another adjunct of the supplies question is forms design. Many benefits can be achieved by using the low-cost snap-out forms. The new "no-carbon-required" paper by National Cash Register lends itself to many uses in the office.

Sorting of such forms as checks and cash stubs may be more easily performed by pre-punched holes.

Another area which is growing in importance is machines. The office has been slower to mechanize than the factory, due to its "characteristics of complexity, variability, and need for logical decisions."* However, with the many scientific breakthroughs, machines are coming into much greater use in the office. Dr. Ernest Dichter, President, Institute for Motivational Research, Inc., in a recent survey sponsored by "Modern Office Procedures" stated:

> "During the next 10 years, the number of computers in active service will increase more than 50,000—15 times as many as are now in use. Most significant of all: 82 percent of computers on the job in 1970 will be small ones. . . . There will be no electronic elite."

Even though most water utility offices will not require the full-time installation of high-speed automation equipment, they will make excellent customers for service bureaus or individual companies having such equipment with capacity for rental.

However, let us not limit the area of automation to the computer field. For "office machines may be defined as devices that aid in the processing of business data, record keeping, or report preparation, and that function mechanically, electrically, electronically, magnetically, or chemically."**

There are many machines on the market which relieve the office staff of boring, repetitive operations. For example, in the mail room there's the high-speed mail openers; mail postage machines which also seal the envelopes; and the newest addition is the mail inserter for small businesses. These machines pay for themselves many times over during their useful life.

In addition to speed of operation and other designed advan-

*Office Management Handbook, Wylie, p. 9-2
**Wylie, "Office Management Handbook."

tages of machines there's the inherent advantage over human beings as pointed out by Gager (IDORT, Vo. 23):

> "People become tired; machines do not. People want extra money for working more than a certain number of hours; machines don't watch the clock. Human workers must be kept happy by pleasant surroundings, proper temperature, cheerful co-workers, music, coffee breaks, personal telephone privileges, holidays, and "pats on the back"; machines have no morale problems. Insofar as machines can be used to replace people, they eliminate unemployment insurance, pensions, hospitalization costs, orientation, vacations, water coolers, and rest rooms, as well as lateness, payroll problems, and labor unions. Employees become ill without notice and there is little that can be done to get them back on the job quickly. Machine breakdowns can usually be forestalled by preventive maintenance and repairs can be effected very rapidly."

The most limiting factor, however, in machines is their inflexibility. They cannot be retrained like personnel to do other operations. And because of this factor it is well to consider flexibility of operation in the original purchase considerations. For example, if buying a billing machine for paper bills, it is wise to have the machine arranged for easy conversion to post-card billing.

With so much development in the field of automation, it behooves the office manager to be constantly acquainting himself with the new developments to insure that the office is not lagging.

These audits bear much fruit. To mention some specifics, permit me to mention briefly some benefits being derived from our office audit at the Portland Water District.

The office personnel has been reduced from a maximum of 19 in 1954 to 15 at present, while there has been the addition of 3385 customers and 36.2 miles of mains.

Comparing the weekly office payroll for the first week of October, 1954, with the first week of October, 1960, the latter was 13 cents more, even though the pay scale of every position has kept pace with the rates prevalent in the community. This, of course, has been possible due to the reduction in personnel.

As a result of changing the customers' billing and accounting from a ledger card system to a stub plan, it takes 17% less time today to account for 32,800 customers than it did in 1952 with 28,600 customers—and with a great deal more control.

By installation of an internal audit program, much of the detail work formerly accomplished by the public accountants in their annual audit is now completed by the office staff. This has resulted in savings in auditing service costs of approximately $1500.00 annually.

By simplifying the various work order forms and standardizing, we are now able to use mass-produced snap-out forms. This accomplished several things: did away with pads and handling of carbon paper; the same information on different types of work orders is in the same location; and saved approximately 10% in the forms cost.

By standardizing the location of addresses on purchase orders, water bills (for those post-card bills which must be enclosed) and reminder notices, only one style of envelope is required.

All full keyboard adding machines are being replaced with 10-key machines. The advantages are faster addition for the average office clerk, greater accuracy for the same reason that a touch typist is more accurate than a "hunt and peck" typist, and less fatiguing.

By using McBee Keysort payroll checks, the time of reconciling the monthly bank statement containing approximately 700 checks has been cut in half.

But all these efforts are simply a means to an end. For the commercial office, the objective is to render better quality service to the customer. For the accounting office, the objective is to measure and weigh the activities of the business which affect the financial structure to the benefit of the owners, management, consumers and employees.

It is my sincere wish to have our New England Water Works Association foster increased communication of ideas and practices applicable to the water utility office by means of regular periodic "general office roundtables." These, I am sure, will greatly contribute to our offices' meeting the challenge of the sixties.

WILL INCREASING RECREATIONAL DEMANDS REQUIRE CHANGES IN PROTECTIVE POLICIES FOR PUBLIC WATER SUPPLIES?

BY CHARLES H. W. FOSTER*

[*Read January 19, 1961.*]

I much appreciate the courtesy of your Association in permitting an outsider to present his views on what unquestionably constitutes a highly controversial subject.

I am here today in my official capacity as Commissioner of Natural Resources for the Commonwealth of Massachusetts, among whose responsibilities fall those problems associated with public outdoor recreation. Yet, as many of you know, Chapter 620 of the Acts of 1956 also provides that the Commissioner shall serve as Chairman of the State Water Resources Commission and, in this capacity, I have been privileged to become acquainted with many of the problems and responsibilities of your profession.

The paper to follow constitutes no criticism of the water works field itself, but merely the ground rules under which it is often required to operate. Neither is there any intent of evangelism in my approach—only an attempt to lay squarely on the table a problem of growing intensity throughout the region.

As fellow resource administrators we face two usual sets of circumstances. No one cares about our field of interest until some sort of crisis develops, thereupon producing action as a result of, rather than in advance of, human difficulty. A second characteristic of our field is that major steps forward tend to be predicated upon a prevalent public vogue. Two outstanding examples of these points lie presently in the fields of public outdoor recreation and water resources.

Facts about Water

Using Massachusetts as an example, water must certainly be classified as one of the region's most abundant assets. With

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1,215 Great Ponds, 11 water bodies over 1,000 acres in size, 4,230 miles of river and stream, and some 3% of its land area in surface water, Massachusetts is considerably more fortunate than the states to the west. An ample, regular rainfall and a sizable but still uncharted system of ground-water reservoirs contribute still further to what would appear to be an area of plenty.

Yet the future promises to hold its share of troubles. According to a report prepared in 1957 by the Legislative Research Bureau, the Commonwealth must face a projected rise in population of nearly 17% by the year 1970, and the per capita consumption of water in Massachusetts is expected to jump from the present 250 gpd to an estimated 350 gpd by the turn of the century. In short, Massachusetts cities and towns must take steps now to meet an anticipated 40-60% increase in total water use by the year 2000.

Facts about Public Outdoor Recreation

The most recent analysis of the state's recreation resources also took place in 1957 with the filing of legislative recommendations by the Department of Natural Resources, based upon a comprehensive study by outside consulting engineers. The report itemized a number of trends contributing to the growing needs of the public for outdoor recreation, pointing out that Massachusetts is now within a day's drive of fifty million people!

The answer seemed to be an accelerated program of acquisition and development at the state level to provide needed public recreation facilities. Also stressed was the need for multiple use of all existing areas in order to meet these demands within the limited framework of a small and already densely populated state.

Role of the Federal Government

In each instance additional recognition has been afforded by serious studies at the federal level. The Senate Select Committee on National Water Resources, established by Joint Resolution 84 of the 86th Congress, has undertaken the herculean job of compiling data on the nation's current water assets and projected liabilities. Similarly, the Outdoor Recreation Resources

Review Commission, authorized by Congress in 1958, has the difficult task of estimating the nation's recreation needs by the year 2000 and presenting an action program designed to meet these objectives.

In each instance national interest has been generated by a state of near crisis common to both fields, for the relentless country-wide population pressure promises to impose upon both fields increasing demands upon essentially fixed amounts of resource raw materials.

Background and Current Status of Protective Policies

In Massachusetts Chapter 111 of the General Laws states categorically that bathing shall not be permitted in sources of water used for domestic water-supply purposes. Relative to other types of recreational usage, the Department of Public Health, by rule and regulation, delegates its authority to local boards of water commissioners who are legally responsible for the safety of their water supplies.

Thus a general law, placed on the statute books in 1884 at a time when few sources of supply were treated, still offers broad prohibitions when all but six surface sources of supply in the state now receive some form of treatment prior to consumption.

What's Wrong with These Policies?

In terms of actual practice, the policies above have produced some curious anomalies, and these are drawn from the comprehensive study of recreation and water-supply reservoirs conducted by the Massachusetts Department of Public Health in 1957.

Of the 61 natural ponds used as water-supply sources listed in the report, half are closed entirely to any form of recreational use. The record of artificially constructed reservoirs is even more severe with 97 out of 150 closed entirely to recreation. Even where filtration is provided, half of the ponds or reservoirs are still restricted from any usage for recreation purposes.

Even where some forms of recreation are permitted, the record is, to say the least, arbitrary. Local regulations range from no use to full use; all uses of the watershed to none at all. Recreation may be permitted year round, restricted to a season,

confined to a two-week period each year, or in one instance limited to Saturdays only. A common practice is to restrict use to residents only, to require a written permit, and in a few instances the privilege of fishing is reduced to the level of political patronage.

There are cases where water from a river system heavily used for recreation purposes becomes inviolable when impounded a few miles distant as a secondary source of supply. Another instance comes to mind where this same policy prevents the use of ponds within a watershed for bathing, despite the fact that the source cannot be used by law for water-supply purposes during the summer months. Perhaps the ultimate occurs in the case of an interstate water body where the portion in one state can be used for bathing, but the other half cannot!

Small wonder that the recreationist becomes increasingly dissatisfied and seeks remedial action in the legislature. Such situations have occurred recently in Connecticut and Rhode Island, and Massachusetts cannot expect to avoid these consequences much longer.

Who Seek These Recreational Opportunities?

Sportsmen have been among the most persistent and articulate in urging relaxed policies on the use of water-supply reservoirs, and there are good reasons why.

A National Survey of Fishing and Hunting, conducted by the U.S. Fish & Wildlife Service in 1955, revealed that there are some 25 million people nationally who seek these forms of recreation each year. Hunting and fishing provide in excess of one-half billion days of recreation to the nation, and the industry they support is worth an estimated $3 billion annually!

In Massachusetts, a detailed study of sportsmen expenditures conducted in 1951 revealed that the Bay State's 300,000 licensed hunters and fishermen spend some $74 million a year—just for the fun of it!

Boating groups have also expressed keen interest in less stringent protective policies. According to the Outboard Boating Club of America some 32 million people took to the water nationally in 1958, accounting for some $2 billion in annual expenditures. This represents a 160% increase in total attendance

over the previous decade, and there would appear to be no slackening of the trend in sight for the moment.

Massachusetts now has nearly 40,000 licensed motor boats over 10 HP, and with its 2,200 miles of coastline and abundant areas of inland water the boating boom has only just begun here in the Bay State.

Vacation-travel interests also play a substantial role in the recreation picture. People concerned with more passive outdoor pursuits, such as picnicking, swimming, camping, or points of scenic or historic interest, combine to constitute the state's third most important industry, estimated at between $300 and $400 million annually by the Massachusetts Department of Commerce.

Will These Demands Continue?

A number of trends contribute to the growing needs of the public for all forms of outdoor recreation. Total population growth is an obvious factor, but equally important has been the movement away from urban centers to the suburbs, thereby exposing more people to the attractions of outdoor pursuits.

A rising standard of living has produced a shorter work week, higher per capita income, and a greater proportion of income available for recreation activities. Personal preferences have also swung noticeably to the outdoors, and the boom in boating and camping nationally are examples of this trend.

But among all the factors responsible for an explosive interest in outdoor recreation, none can match the astonishing mobility of the American people. Thanks to an expanding system of new highways and the automotive convenience now standard in the American home, outdoor recreation is within reach of any family today.

The result has been soaring attendance at national parks (62 million visitors in 1959), national forests (81 million visitors in 1959), and state parks (255 million visitors nationally in 1959). Massachusetts state park attendance has risen approximately 10% each year for the past three years, and these areas now serve one and one-half million people annually.

These statistics lead to some obvious conclusions. There are serious needs to be met in the recreation field, and they must

be met wherever opportunities present themselves. Recreationists are numerous, often well organized, and represent substantial contributors to the region's economy. As users of water in its many forms, they are your constituents as well as mine, and their voices should therefore be taken seriously.

Arguments Against Change

The arguments against change are numerous and deeply rooted. As a recreation administrator I have heard many of them, and here are my efforts in response.

Hazard to Public Health

There are those who will state categorically that a rigid protective policy is the public's only dependable safeguard against instances of water-borne disease. They cite, for example, the Commonwealth's excellent record relative to typhoid in recent years. Certainly water-supply officials deserve a major share of the credit for drastically reducing the incidence of this terrible disease within the space of the last half century.

Yet it is equally obvious that the many technological advances in sanitary engineering have not been reflected in any substantial relaxation of protective policies here in the northeast, despite the fact that other sectors of the country have accepted multiple use as a matter of course.

The midwestern states offer classic examples where even grossly polluted water is reprocessed for domestic consumption, and the same is true for much of the south. New York State has permitted recreational use of its reservoirs since 1905, and even in Massachusetts water from the Merrimack, Ipswich, and Concord Rivers is utilized for domestic consumption, despite the fact that it is also heavily used for recreation purposes.

The Sport Fishing Institute reported recently that there are only six states where the majority of municipal water-supply reservoirs are closed to public fishing, and half are located in the northeast. It would appear that our region is either substantially ahead or behind the rest of the nation!

Other Sources Available

A second common pronouncement is that the availability of other areas precludes the necessity of opening reservoirs to recre-

ation in the immediate future. Why not develop other sources, the opponents contend, before seeking areas already serving a major public purpose.

In Massachusetts, for example, only ten percent of the natural ponds over ten acres in size are reserved for water-supply purposes, and since 1940 not a single Great Pond has been taken by any municipality for such purposes. Yet by virtue of current restriction, municipalities have removed some 26% of the state's natural surface water (ponds) from recreational usage. In the case of one county (Essex) this total reaches 58%.

It is evident from these statistics and the recreation trends previously cited that the pressure on available surface water is certain to mount steadily in the future and that localized shortages for recreation are a matter of record even in the present.

On the development of purely recreational sources, a small state such as Massachusetts has only a limited number of sites. In many instances, those of the greatest economic feasibility have already been spoken for by domestic or industrial users. Recreationists contend that a sound and sensible policy of multiple use can obviate the necessity of substantial public expenditures for single-purpose recreation projects, at least in the foreseeable future.

Reservoirs Have Limited Value for Recreation

Fishermen are frequently confronted with statistics showing the limited poundage of fish salvaged from water-supply reservoirs where programs of restocking are conducted by state fish and game agencies. Although a fisherman's fancies are classically out of proportion to reality, this argument against change has the least merit of all.

The key to effective fish management is, where possible, control of the water level, and fisheries practices can in many instances be fully compatible with a regular water-works program. For example, late summer drawdowns are often recommended by fisheries experts in order to concentrate populations of warm water fish. This means that competing species can be utilized effectively by game fish as forage, thereby reducing the likelihood of overcrowding. In a normal water-supply reservoir, levels would tend to be at their lowest naturally in

August and September and would therefore be quite compatible with fisheries objectives.

Furthermore, technicians can work wonders with almost any impounded body of water by policies of stocking and natural growth. At Quabbin Reservoir, for example, brown trout introduced in the spring, weighing one-quarter pound each, were recovered by fishermen in the fall weighing two pounds each, a phenomenal record of growth made possible by the abundance of natural food and absence of competition from other species.

Recreation administrators also know that pond and lake fishing can offer one of the most efficient types of recreation opportunity. Small ponds in urban areas, for example, can support 1000 hours of fishing per acre per year, far in excess of their rural counterparts. Comet Pond in Hubbardston, some 65 miles from the Boston area, produced 200-300 hours of fishing per acre in 1960. Quabbin Reservoir recorded over 90,000 angler trips this past season but only 18 hours per acre of fishing pressure.

For other types of recreation, water is almost invariably the prime requirement, and water-supply officials should pay little heed to the argument that reservoirs have little recreation potential. Aside from the water itself, such reservoirs are usually surrounded by attractive wooded areas, located within easy reach of populations, of sufficient size for efficient development, and exhibit the type of previous care and maintenance which would make them of prime recreation value.

Reservoirs Built Strictly for Water-Supply Purposes

Another common objection involves the fact that reservoirs were financed and built for water-supply purposes alone. Waterworks officials frequently complain that recreationists seek privileges without being willing to share the financial and legal responsibilities assumed by the water users. There is some validity to this argument, because the recreationist, used to his conservation raw materials free of charge, is apt to consider such proposals rank heresy!

The recreationist, on the other hand, can frequently rebut by pointing out that his interests were preempted without compensation when the area was originally developed. He may con-

tend further that the additional usage could be achieved without detriment to the primary function of the reservoir for water-supply purposes. He also may argue that, as a water user himself, he ought to be given some choice in the matter before the decision is made to restrict recreational usage.

Who Should Pay?

There would seem to be little question that where additional treatment is warranted in order to permit recreation, the latter interests should pay their share. However, the recreationist should not be required to shoulder this financial burden automatically without a prior determination of the need.

Springfield, Illinois, is a case in point. Faced with the need for an additional surface source, water-works officials carefully planned the location and costs of the proposed reservoir. When the proposal was placed before the voters, it contained alternate cost estimates based upon full or limited recreational usage. Fuller usage, though more expensive, won out.

It would appear equally inappropriate, however, for the water user to have to bear the financial burden of servicing the recreationists' needs. If the area is used for such purposes, the user should naturally be prepared to pay a reasonable fee for the privilege.

Arguments for Change

It is the author's contention that the present restrictive policies governing broader usage of water-supply sources frequently constitute a shocking waste of a valuable resource, in many instances to the direct economic disadvantages of a municipality. *In a densely urbanized state such as Massachusetts, multiple use, where feasible, must be a basic principle of land and water management.*

Unrealized Economic Benefits

Over 150,000 acres of forest land are presently held for watershed protection purposes in Massachusetts, land fully capable of sustained production of wood products. Yet less than 20% of this acreage is estimated to be under adequate forest management at the present time. Given the same degree of professional service afforded the rest of the water-supply system,

these watersheds could be returning upwards of three-quarters of a million dollars in annual income to their respective municipalities.

Would water yields suffer under intensive forest management? Recent studies indicate to the contrary. Specialized practices have been developed for water-supply watersheds which include species changes, strip cuttings to encourage snow storage, and thinnings to reduce interception and transpiration. Such programs can be undertaken commercially with valuable returns in both water and wood products.

Also on the economic side, it is perfectly feasible to anticipate a recreational usage which will, at the least, pay for itself. Recreationists do not object to paying for facilities which are provided for their comfort and convenience, and it might well be that the municipality could reap a modest income from the operation of certain recreation facilities. It is my understanding, for example, that the facilities for fishermen at Quabbin Reservoir are now being operated at an annual profit to the water users of metropolitan Boston.

Improved Protection

Where recreation functions are given proper recognition, rather than permitted to flourish surreptitiously, the water user may actually receive better sanitary protection at the source under multiple use. A basic principle of any recreation development is to limit entrance and exit points in order to gain effective control of recreation users. A logical rule of thumb might be to open those reservoirs and drainage areas to controlled recreation where proper standards cannot now be effectively enforced.

Recreational Needs

Also on the side of an economic asset are the problems being faced by the communities in providing adequate recreation facilities for their own citizens. There is an astonishing degree of interest to this end in Massachusetts through the efforts of newly authorized city and town conservation commissions.

Where such facilities can be provided at water-supply reservoirs, the municipality may be relieved of substantial added financial burdens. In fact, the cost of providing additional treat-

ment to permit multiple use may be well below that of acquiring and developing a new area for recreation purposes alone.

Other Benefits

In some urban communities, the reservoirs and protected watershed constitute the only sizable green space remaining! In terms of increased property values, sound future development of the community, and supplemental services these values may even outweigh the primary function as a water-supply source.

Many municipal water departments have difficulty selling the need for improvements to their systems because people have come to expect good water at a price ridiculous to mention. By narrowing their functions to just those of water supply, these officials tend to isolate themselves from general public support. From just a socio-political point of view, the recreational use of reservoir properties could serve as a valuable source of public relations and contribute to a better understanding of total water problems by people within a given community.

Summary

In summary, therefore, the chief barriers to the relaxation of restrictions governing public use of water-supply reservoirs would appear to be, on the surface, not technological but legal. Although the law itself contributes the primary obstacle, there are substantial areas of support from the outside. Among these would appear to be the following.

Tradition, as is frequently the case, has its negative, as well as positive aspects. On the plus side are the prime sources of supply in which the northeastern United States takes such justifiable pride. From a long-term philosophy of careful protection, however, stems the natural resistance to change which currently represents a major part of our present difficulties.

Economics also plays an important role. New England water users are secure in a low-cost, high-quality type of water-supply system to the point of taking it for granted. Both sides agree that increased recreational usage would often require additional treatment, hence additional unit costs carried either by the consumer or by the recreationist. *My point here is that the consumer should at least be asked before the decision is made!*

Convenience is also a third factor contributing to the reluctance to change. Few water-works officials look forward to the complications certain to evolve from the increased usage of their area by the public.

Lastly, a situation essentially *political* must also be cited. Unfortunately, many water-supply areas, although public property in every sense of the word, actually have all the attributes of private domain. Any intrusion for added public purposes is certain to be resisted.

Recommendations

Before citing a few suggestions designed to bring the recreational use of water-supply reservoirs in sharper focus, let me emphasize several points that I am *not* making!

Do I advocate the wholesale abandonment of all past standards in favor of a more relaxed set of protection principles? I definitely do not!

Do I advocate the immediate introduction of corrective legislation which would modernize the basic statutes in this regard. I do not at this time.

Do I favor a massive campaign by recreationists to lower the barriers against multiple use of reservoir areas? I obviously do not!

What I do recommend, however, is a realistic reappraisal by the water-works profession itself of the technological advances in its field as they pertain to recreational uses. This serious study should be undertaken in a fashion to reflect present trends throughout the country, not just to echo the thinking in fashion several decades ago. The place to start would be your Association, which has a long tradition of the highest public service, but which also has in its midst many individuals who must face the practical aspects of multiple use every day.

To make doubly sure, let me stress again that I favor voluntary sensible change, not crisis action. I am equally convinced, however, that unless your profession becomes more aware of the inconsistencies in its present policies and takes voluntary corrective action, it may shortly face unilateral action which could swing the pendulum towards a type of under-protection which none of us would like to see.

Your Association should form a committee, not just of water-supply officials, but also of representatives of recreation interests. Talk to others besides yourselves, and I think you will be surprised at the degree of sympathy towards your particular problems—even by the recreationist!

The next step would be to inventory actual multiple-use situations in the region. This could prove enlightening, because you may discover a sizable number of situations where the current law is either overlooked or, at the least, unenforced. It is all part of the problem and therefore should be included.

I would urge that you approach this area *positively*, not negatively. Attempt to define realistically the benefits from increased multiple-use, as well as its drawbacks, and see where it would make sense as well as where it wouldn't. If you do this, you will get wholehearted support from the recreationist for those latter cases in which multiple-use is not in the public interest.

The Association should call upon representatives of the water resources boards and commissions in the northeast, who are charged with broad policy responsibilities in all fields of water development and management. Another candidate organization would be the Northeastern Resources Committee, which consists of representatives from seven federal agencies as well as one from each New England State.

The committee should be a working committee with a deadline for reporting. Its objectives should be simple and constructive—to define a common middle ground for the water-works official and recreation administrator alike, which would enable these resource officials to work together, defend each other's positions, and produce for the public a set of realistic benefits, designed to maximize the return from the latter's original investment in land and water.

I consider this a challenging objective for your Association, but one entirely in keeping with others you have accomplished successfully in the past. Let me say that these thoughts are not advanced irresponsibly, but with the firm pledge that any help my office can provide will be yours for the asking.

NEW WATER FILTRATION PLANT—KITTERY WATER DISTRICT, KITTERY, MAINE

BY PAUL F. HOWARD*

[*Read February 16, 1961.*]

The original water supply, installed by the Agamenticus Water Company, supplied water from Middle Pond to the Portsmouth Navy Yard, commencing in 1904. The inhabitants of Kittery Village also wished to be served by the Water Company. This desire resulted in the formation of the Kittery Water District in 1907, and the acquisition by the Water District of the existing water system.

The Kittery Water District now supplies water service to the entire Town of Kittery, parts of the Towns of York and Eliot, and also the Portsmouth Navy Yard which is located in Kittery.

Reservoirs

The water supply is obtained from three impounding reservoirs about seven miles northeast of Kittery Village in the Town of York and from a small spring located in the Town of Eliot.

The reservoirs, known as Folly and Middle Ponds (see Fig. 1), are located in the same watershed and have a combined capacity of 550 million gallons. The area of watershed including the water surface area is about one and one-third square miles. The Boulter Dam was constructed in 1950 which formed the Bass Cove Reservoir that has a capacity of 500 million gallons and a watershed of 2.3 square miles. These reservoirs, together with the small Cottle Spring supply from Eliot, have a combined dry-weather yield of about 3.2 million gallons per day.

The original Middle Pond Dam was constructed of stone and mortar and was raised with concrete during the first World War. During the second World War the increased demand was met by building the Folly Pond Dam and pumping water from Chases Pond to Middle Pond.

* Whitman & Howard, Inc., 89 Broad St., Boston 10, Mass.

POND
CHASES POND
N.
FOLLY POND
MIDDLE POND
DAM
DAM
SCITUATE POND
2-12" MAINS
BASS COVE RESERVOIR
SCREEN HOUSE
CHLORINATOR HOUSE
BOULTER DAM & PUMPING STA.
TREATMENT PLANT
12" MAIN
16" MAIN
12" MAIN
12" MAIN
YORK
16" MAIN
RIVER
12" MAIN
12" MAIN
16" MAIN
BOOSTER STATION
12" MAIN
12" MAIN
8" MAIN TO ELLIOT
SPRUCE
12" MAIN
12" MAIN
CREEK
STANDPIPE
KITTERY
2-12" MAINS
16" MAIN
SUPPLY WORKS
KITTERY WATER DISTRICT
KITTERY, MAINE

FIG. 1

The water from Folly Pond discharges into Middle Pond, which has a full reservoir elevation of 226 feet above Mean Sea Level. As desired, the water from this reservoir runs directly to the Filter Plant or to the Bass Cove Reservoir, which has a spillway elevation of 75 feet.

However, if required at any time, the water from Middle Pond can be supplied directly to the distribution system at sufficient pressure without filtration—but with chlorination and eel straining, as in the past, by opening and closing certain valves.

Water Consumption

During the year 1960 the Kittery Water District supplied an average of 2.3 million gallons per day. The greatest quantity supplied in any one day was 3.94 million gallons.

The Portsmouth Navy Yard and other Federal agencies used an average of 1.25 million gallons per day in 1960. The quantity of water used by the Navy Yard has varied greatly from time to time with the changes in activities due to wars and the threats of wars. These changes in water demand have made it very difficult for the Trustees to determine how much indebtedness should be incurred to satisfy them. The question has always been, will the Navy Yard continue to provide enough revenue to pay for its share of the required capital investment?

Water Quality

There are no buildings or highways located on the watersheds. The water supply in the past has been quite highly colored and at times had a noticeable taste. Like so many reservoirs at times these reservoirs have had substantial growths of algae and other microscopic organisms, which have imparted objectionable tastes and odors to the water. In 1958 the water as drawn from the taps in Town contained small organisms of the Crustacea family which were visible to the naked eye in a glass of water. Their short, quick darting movement attracted the attention of the water consumers. This was the final blow. The Trustees then voted to build a filtration plant with the required standpipe and pumping facilities.

General Arrangement of Facilities

In order to keep the cost of operation at a minimum, it was decided as follows:

(a) Make pumping station at Boulter Dam entirely automatic by means of pressure controls.

(b) Make pre- and post-chlorination automatic in proportion to the quantity of water flowing.

(c) Construct standpipe in Kittery Village near point of maximum demand in order to provide needed local storage. The standpipe would cause less variation in water pressure, which would allow the use of pressure controls to operate the large motors driving the supply pumps, located seven miles distant at Boulter Dam.

(d) Construct filter plant that would be so automatic as to require an operator one shift per day, five or six days per week, and an inspection the other days.

Filter Plant

The filter plant is located near Bass Cove Reservoir just below the Boulter Dam at such an elevation that water flows by gravity to and through the filter plant to the pumping station (Fig. 2).

The rate of flow from the reservoir to the filter plant is controlled by means of a Dall tube and butterfly valve type rate-of-flow controller installed in the 16″ supply main. This controller, in turn, is actuated by the discharge rate from the pumping station into the distribution system. An over-riding control from the water level in the clear well is provided, so that the clear well will always be substantially full.

The plant was put into operation on March 30, 1960, and has run continuously since then, except when shut down for manually cleaning the coagulation and settling basin. This continuous operation is made necessary primarily by the demand of the Navy Yard.

The water enters the flocculation chamber through a flash mixer having a detention period of 10 seconds (Fig. 3). The flash mixer is a small concrete chamber with an electric motor-driven stirring device. Alum and lime are added in the flash mixer. Liquid alum is applied through small chemical feed pumps. Lime is applied by usual dry chemical feed machine

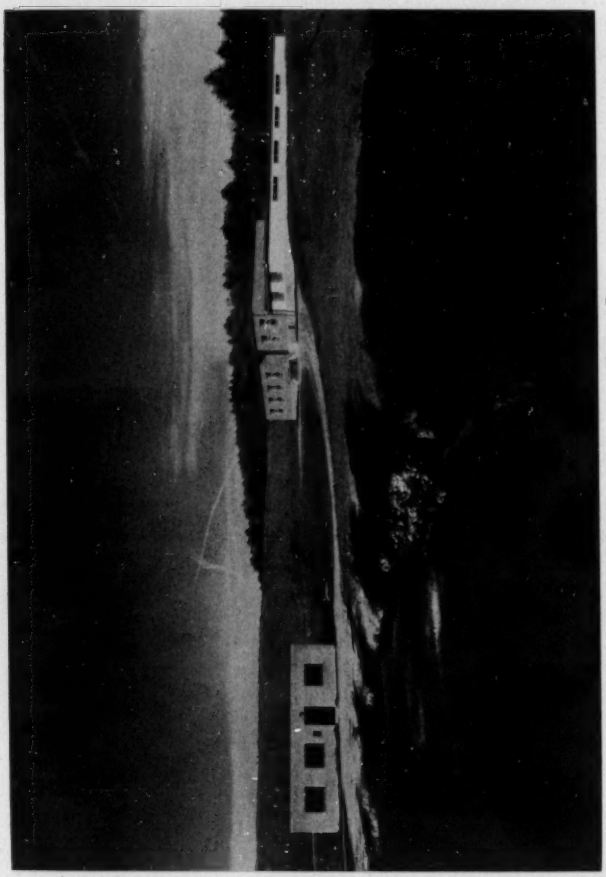
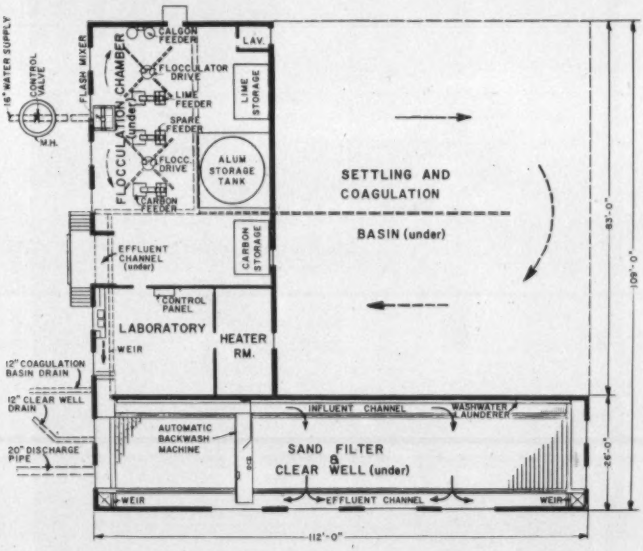


FIG. 2—PUMPING STATION AND FILTER PLANT

with built-in load elevator and dust collector (Fig. 4): Dry chemical feed machines similar to the one used for the lime are used to feed activated carbon and soda ash into the flash mixer or the effluent channel from the coagulation basin, as desired.



PLAN — WATER FILTRATION PLANT KITTERY, MAINE

FIG. 3

The application of chemicals varies directly with the rate of flow into the plant, by means of an electric time-impulse type control, actuated from the raw-water Dall tube. The rate of application is arranged so as to be manually changed in the usual way.

The use of chemical feed machines, each with built-in elevators, and the use of liquid alum saved substantially in construction cost, as it eliminated the necessity of building a second story

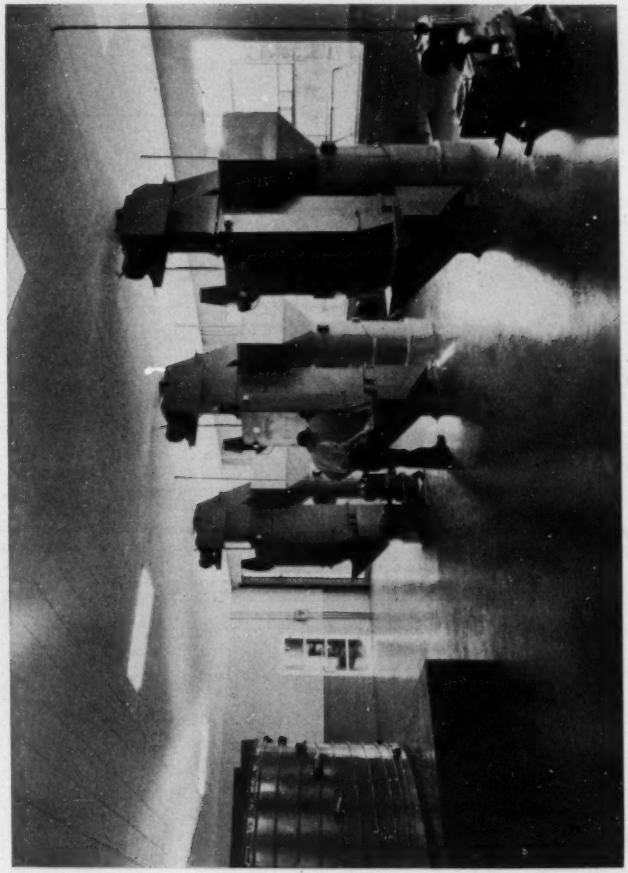


FIG. 4—CHEMICAL FEEDER

to the building for storage of chemicals and eliminated a freight-type elevator. The additional cost of increasing the floor area was relatively small, as the foundation, floor and back wall were required in any case.

Hexametaphosphate for corrosion control is fed into the 20-inch effluent line from the filter plant to the pumping station.

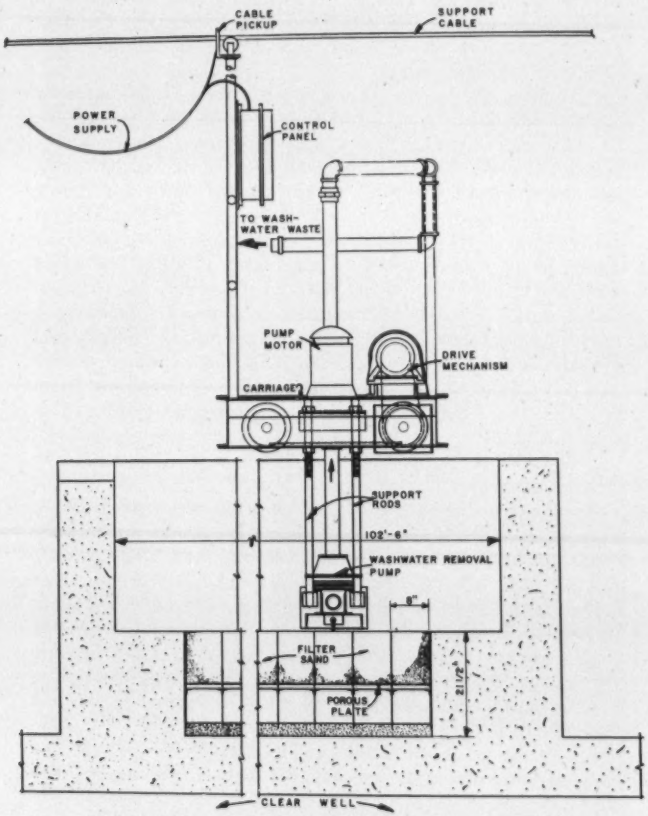
The water from the flash mixer is discharged into the flocculation chamber, which has a detention period of 24 minutes at the design flow of 5 million gallons per day. Both flocculators are of the vertical type, and each has two arms with paddles at two elevations. The speed of the flocculators can be varied by means of mechanical drives from 1 rpm to 3 rpm. The water flows from the flocculation chambers to the settling and coagulation basin through a wooden partition so arranged as to have an advantageous baffling effect. At the design rate the settling and coagulation basin detention period is four hours with a surface overflow rate of 565 gallons per square foot. The settling basin is of the around-the-end type; i.e., it has a wooden middle partition wall.

The sludge (settled floc, etc.) is drawn from the basin for cleaning purposes through a 12-inch mud valve located at the low point of the basin and is discharged into a nearby brook.

Since the plant was put into operation the basin has been drained four times. The draining, cleaning and filling process takes about 10 hours. During this cleaning period the water supply to the Town by-passes the settling and coagulation basin and flows directly to the sand filters. The color of the water served the users during this cleaning period does not become very high as the water, after it passes the filters, is diluted by the clear-well water and the water in the distribution system and standpipes.

The water from the settling and coagulation basin discharges over an aluminum weir to a concrete channel, and thence onto the sand filter.

The sand filter operates at the rate of 2.2 gallons per square foot per minute, at the design rate of 5 million gallons per day. The filter is of the automatic backwash type, having a sand depth of 11 inches supported on porous plates (carborundum). The filter is broken up into 150 compartments, each 8 inches wide



SECTION THRU SAND FILTER & AUTOMATIC BACKWASH MECHANISM KITTERY, MAINE

FIG. 5

and 16 feet long. The filter sand has an effective size of 0.55 to 0.65 mm. and a uniformity coefficient of 1.5. The compartments are constructed of heavy steel plate, which were coated

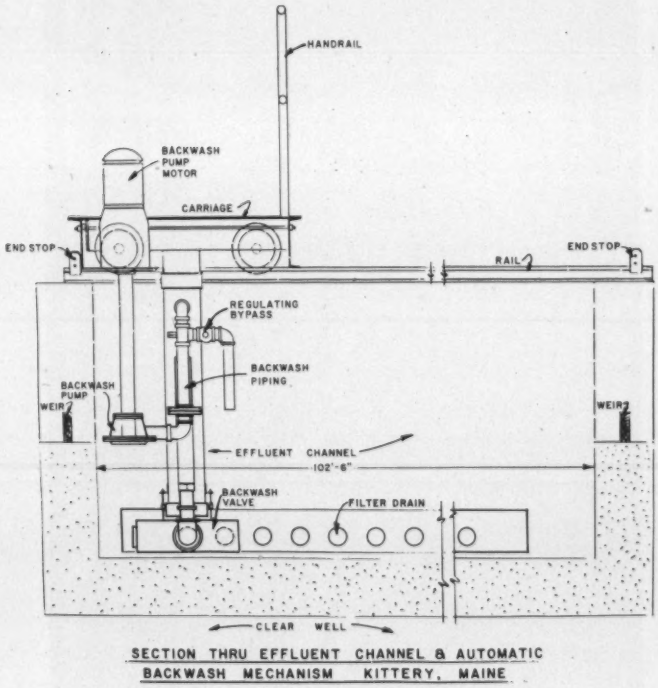


FIG. 6

with a special heavy bituminous coat at the factory, and with another coating after erection. The filter is so arranged as to be automatically backwashed when the loss of head becomes more than 2½ inches, or a minimum of once in eight hours.

The backwashing arrangement (see Figures 5, 6 and 7) is

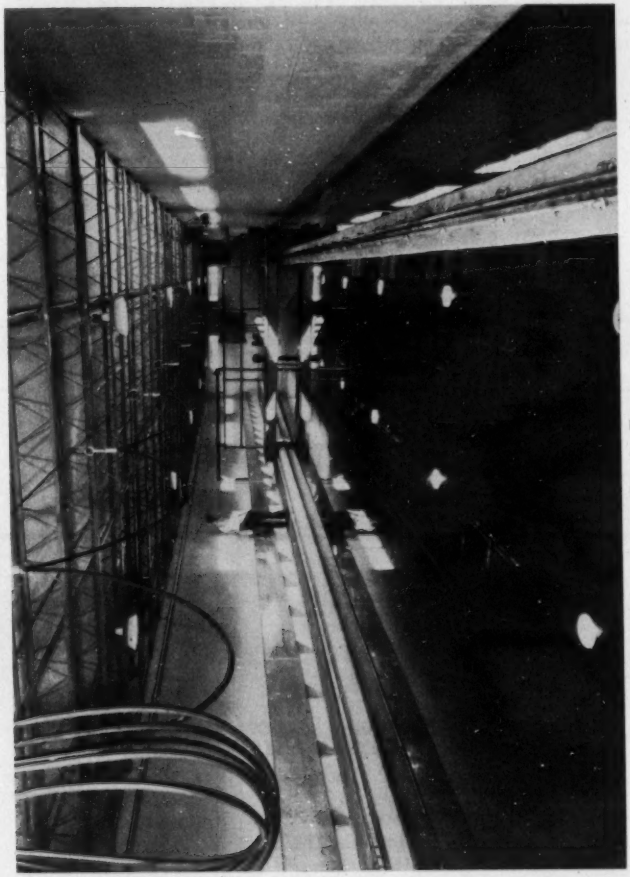


FIG. 7—FILTER

accomplished by washing each compartment individually. A backwash water pump with 1½-horsepower motor, having a capacity of about 150 g.p.m., is supplied from the effluent channel and discharges as it moves along on the carriage into each individual compartment under each sand filter compartment. The wash water flows upward through the porous plates and sand into a traveling hood. A second pump with a 1-horsepower motor transfers the dirty waste water from the traveling hood to the wash-water launderer, which in turn discharges the water into the drainage system leading to the brook.

The backwash pumps are mounted on a carriage that spans the filter and runs on a rail on each side of the filter. The backwash carriage moves at a rate of about 2 feet per minute and is driven by a ¾-horsepower electric motor.

The water discharges from each end of the effluent channel over adjustable weirs into the clear water basin below. The weirs are adjustable as to height in order to assure the filter's being flooded to the desired depth. In practice, once the weirs are set they seldom need to be changed. The clear well is located under the sand filter but is isolated from it by means of a reinforced-concrete roof. The clear well has a capacity of 260,000 gallons.

The plant has been very effective in removing color, taste and odor from the water. The raw water had colors ranging from 30 to 70, and the effluent of the plant has had a color from 0 to 5. The raw-water iron content is .4 p.p.m. to .5 p.p.m., and the effluent iron is .06 p.p.m. All objectionable tastes and odors have been eliminated from the water since the plant has been in operation. However, one day a customer located in York near the plant notified the water superintendent that the water contained a disagreeable odor. Investigation revealed a substantial growth of Asterionella algae in the reservoir. Immediately, activated carbon was applied to the water ahead of the filter, with the result that the odor disappeared and the odor-free water was so mixed with the water containing odor that, by the time it reached throughout the distribution system, it was not apparent in Kittery.

Floc formation had been satisfactory by the use of alum and lime until the extreme cold weather set in, when it has been

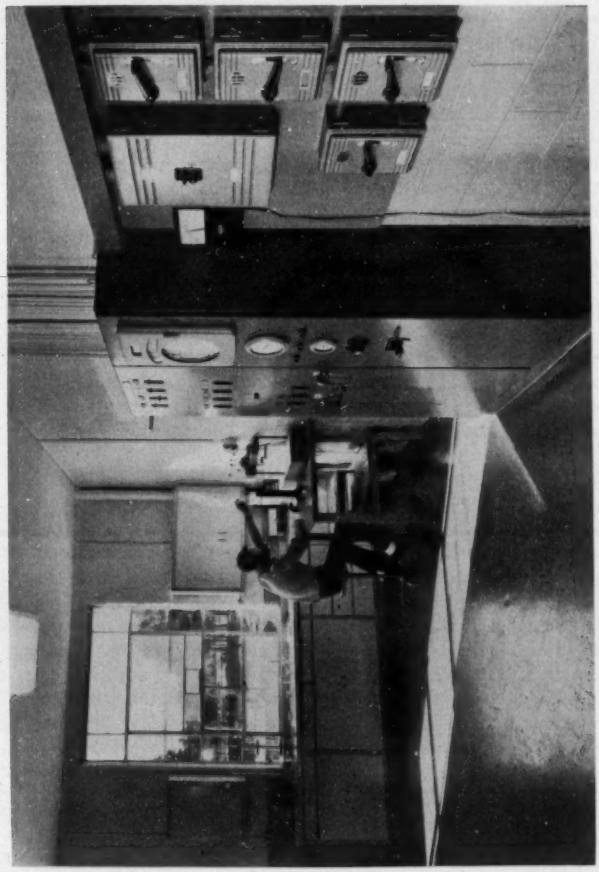


FIG. 8—LABORATORY

found advisable to use soda ash for final pH correction. Previous to the application of soda ash, as the water got cold, it was found necessary to reduce the lime and the alum to a minimum in order to prevent the carry-over of floc in the distribution system, with a resultant lowering of the pH of the effluent.

Generally speaking, the filter plant controls are of the pneumatic type with air pressure of 3-15 lb.

The influent to the plant is metered, based on the flow through a Dall tube, by a meter which indicates, records and totalizes the flow. The clear-well water level is shown by an indicator gage at the control panel.

The building is automatically heated by means of oil-fired hot water boiler and unit heaters.

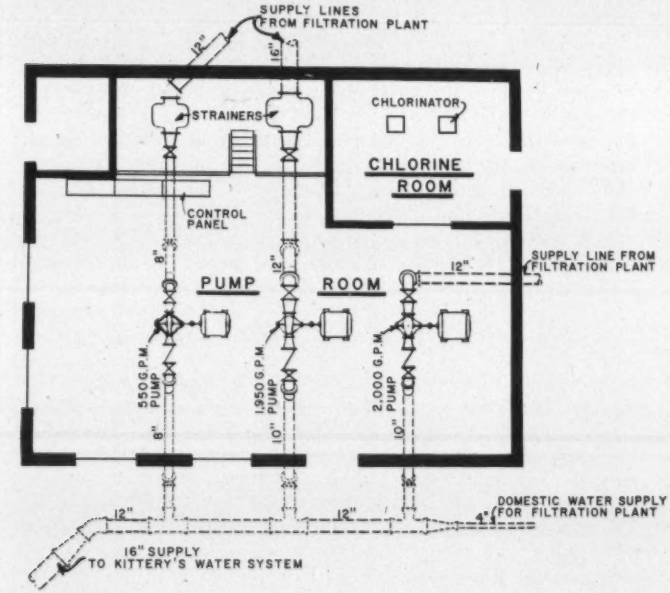
A laboratory with the usual equipment was provided, including a six-jar variable-speed mechanical mixer for determining the best chemical dosage for the formation of floc (Fig. 8).

The coagulation and settling basin and clear well are constructed of reinforced concrete. The building is constructed above the basins, so that the roof of the basin is the operating floor, and the roof of the clear well is the support for the filter. The portion of the settling basin that is not under the building is covered with 2½ feet of earth to prevent freezing. The building walls are of 12-inch-thick concrete blocks, except the front portion of the building, which is constructed of 8-inch concrete blocks on the inside with a 4-inch brick facing on the outside. The roof of the building is of bar joist construction, supporting a 3″ plank roof (wood fiber and portland-cement type plank) with tar and gravel finish.

Pumping Station

Water from the clear well flows to the pumping station, which houses three electric-motor-driven centrifugal pumps (Fig. 9). These pumps are automatically controlled by the pressure from the discharge line, which substantially reflects the water level in the standpipe. The controls for these pumps are so arranged that the discharge pressure determines which pump or combination of pumps shall operate to meet the demand, so that, in actual practice, there are five pumping rates, varying

from 550 gallons per minute up to 2,800 gallons per minute, except when the demand is so great that the Kittery booster pump operates. Then the discharge rate is increased to 3,200 gallons per minute. No gasoline or diesel engine-driven standby



PLAN - PUMPING STATION - KITTERY, MAINE

FIG. 9

pumps are provided. In case of power or other failure the water from Middle Pond can be chlorinated, strained to remove eels and supplied directly to the distribution system with existing facilities.

Automatic chlorination has been arranged for both pre-

and post-chlorination from the chlorinators housed in the pumping station. However, it has not been necessary to use post-chlorination, as the effluent from the filter plant has contained sufficient chlorine.

Outline of Automatic Process

As the demand on the distribution system varies, the water level in the Kittery standpipe is reflected in the pressure at the pumping station. These variations in pressure are used by means of pressure-controlling devices to create five different rates of pumping to meet the changes in demand.

As the rate of pumping varies, the Dall tube located in the discharge main from the pumping station sends a differential pressure signal by means of air pressure to the rate-of-flow controller, consisting of a Dall tube and butterfly valve located in the supply line to the filter plant, thus making the rate of flow to the filter plant equal to the rate of pumping.

As the flow to the filter plant varies, the Dall tube located in its supply main sends a signal by means of air pressure, converted to an electric impulse signal, to proportion the application of alum, lime, soda ash and carbon, in order to maintain a uniform rate of dosage. The rates of dosage are readily set manually.

The filters are automatically backwashed, based on loss of head through the sand filter, and have an over-riding time-clock control to work at any predetermined time interval, if desired.

The feeding of hexametaphosphate is likewise controlled from the Dall tube located in the discharge main from the pumping station.

The chlorination system is so arranged that either or both chlorinators can be used for pre- or post-chlorination. In a manner similar to that used for feeding chemicals, the Dall tubes are used to vary the amount of chlorine feed with the flow of water, so as to maintain a uniform rate of application.

If for any reason the clear well empties, an over-riding control system will shut off the plant until conditions become normal. All automatic devices have spare or alternate manual controls.

Costs

The entire cost of the filter plant, the addition of one 2,000-gallon-per-minute electric-motor-driven pump, new electric controls, one new chlorinator, outside piping and alterations was $440,000, which equals about $88,000 per million gallons per day capacity.

The cost of operation has been about $44 per million gallons. This cost includes all labor; electric power for pumping, filtering and lights; chemicals, heating oil, etc.

Not only has the cost of construction been reduced to about 60 per cent of the cost of the conventional plant, but the man-hour requirements for operation per week have been reduced from 168 to about 46. These 46 hours include the time required each day for the operator to check the Cottle Spring supply, the standpipe and booster pumping station.

Acknowledgments

The plant was designed by Whitman & Howard, Inc. The design and construction were both under the direction of Roger Disken, and the resident engineer in charge was Myles F. Howard.

On October 1, 1960, the plant was dedicated and named the Francis L. Hatch Filter Plant in memory of Mr. Hatch, who was Superintendent of the Kittery Water District for 30 years. Mr. Hatch died during the early stages of the work and was succeeded by Mr. Harry N. Wyman, the present Superintendent, who is also responsible for its operations.

The entire project has been under the direction of the Trustees of the Kittery Water District. For about twenty-five years the author has had the pleasure of working with the Trustees and here does acknowledge with gratitude the cheerful, sincere and cooperative association with the Trustees during this period: namely, George D. Boulter (deceased), Elmer J. Burnham, Burnell E. Frisbee and Edward E. Shapleigh, Jr.

TWO-TANK FAILURE AT NEW LONDON, CONNECTICUT

By CLIFFORD S. MANSFIELD*

[*Read February 16, 1961.*]

Suddenly on the morning of September 5, 1960, about 9:30 a.m., two of the City of New London's three prestressed concrete water-storage tanks at Lake Konomoc failed.

The two-tank failure represented a loss of about 3.3 million gallons of water-storage capacity, which was about one third of the City's total distribution water storage. The local paper printed only a short story regarding the failure and, to the best of my knowledge, the failure received little or no publicity elsewhere. A sudden, 3.3-million-gallon, water-storage tank failure probably would be considered a disaster in most cities and normally would receive wide-range publicity; however, at New London (1) distribution system water pressure was not lowered; (2) water service in the City was not interrupted; and (3) there was not any property damage.

The Konomoc water storage tanks are located about six miles west of the City. The tanks are about 90 feet in diameter, the water depth is 35 feet, and their base elevation is approximately the same as the overflow elevation of water storage in the City. At the time of the failure, water storage in the City was approximately at overflow level; therefore, the sudden failure had little or not effect on the distribution system pressure. The water storage capacity in the City is about 4.5 million gallons, and the City's water supply capacity exceeds maximum daily water consumption requirement; therefore, there was not an interruption of service. Property damage was nonexistent because the only building near the Konomoc tanks is the City's water pumping station and the four feet of water which found its way into the basement did not damage the pumping equipment. Actually, only the rabbits that rode down the hill in the four-foot wave of water and the City employees

*Senior Engineer, Fay, Spofford & Thorndike, 11 Beacon St., Boston, Mass.

who were summoned to operate gate valves on a holiday morning were disturbed by the failure.

Fay, Spofford & Thorndike was engaged by the City of New London to investigate (1) the cause of the failure; (2) the adequacy of the remaining water storage; and (3) the future value to the New London water-works system of the remains at the Lake Konomoc tank site. The paper will cover only items relative to the cause of the failure.

The three Lake Konomoc water-storage tanks were constructed about 17 years ago. Construction was completed in 1943, and except for a period in 1944 when some leaks were repaired, the tanks have been in continuous service. Record information relative to the design and construction of the tanks is not complete. However, we were able to compile fairly accurate information by procedures which follow:

(1) Inspection of the site after the failure.
(2) By viewing the City's movie film made during construction of the tanks.
(3) By a review of the City's copies of specifications and drawings prepared by its engineering consultant.
(4) By a review of the Contractor's shop drawings prepared for the tank construction.
(5) By interpretation of the results of leakage tests of pertinent piping made after the failure.

The contract specifications and drawings provided for excavation at the site to be at least 12 inches below the bottoms of the tanks. In addition, elevations established for appurtenant water mains in the area required trench excavation between the tanks about 6 feet below the tank bottoms. Well compacted backfill material for pipe trenches was specified with concrete encasement for pipe under the tanks. The specifications further required that the area under each tank be uniformly graded and then covered with a 12-inch well compacted layer of sand.

The tanks were constructed by the pneumatic mortar method (Gunite) using the 12-inch sand layer for foundation. The twenty-eight-day design compression strength was 5,000 psi minimum in the floor and walls and 4,000 psi minimum in the dome. The prestressing force was designed to be obtained

with rods proportioned and initially stressed so that when the reservoir was full of water, there would be no tension in the concrete, and the tension in the rods would be safely below the yield point. However, when the tanks were built, the steel rods were used only for dome ring prestressing, and the tank walls were prestressed with wire. For leakage, visual inspection and water-level measurements were required.

Inspection of the site after the failure indicated that construction closely followed the drawings and specifications. The tanks were built on a sand foundation about 12 inches thick. The sand was placed on a variable foundation which included concrete encasement around the inlet and outlet pipes, undisturbed ground, ledge formation, and gravel backfill used to replace ledge excavation. The sand foundation was not confined by a ring wall or other means. There were a 24-inch cast-iron supply pipe and a 24-inch cast-iron discharge pipe in trench between and adjacent to the three tanks. The pipe trench was about six feet below the tank bottoms, and inspection indicated that some of the trench was in rock excavation. The two tanks which failed are less than 15 feet apart, and the failure occurred at their closest points. It appears that parts of the tank bottoms at the point of failure were supported on the material used to backfill the pipe trench.

After the 12-inch sand foundation was in place, a "Gunite" slab, reinforced with wire mesh, was placed to form each tank bottom. The wire mesh reinforcing was laid on the sand and the Gunite was placed upon the sand and mesh. The Gunite encasement of the mesh between the mesh and the sand is variable, and in some places the mesh has no Gunite covering. The tank walls were constructed on the Gunite slab without any wall footing. To prevent relative movement between the bottom slab and the wall, the two were joined together with reinforcing rods placed in the Gunite floor slab and bent up into the wall. To finish the joint between the floor slab and wall, a Gunite cove was built around the inside of the tank.

On Figure 1 the tanks are designated as Tanks No. 1, 2 and 3. Tank No. 1 and Tank No. 2 failed. We believe Tank No. 2 was the first to fail, this belief being substantiated by the fact that its roof slab was on the floor and covered with gravel

and boulders deposited by the wave of water from Tank No. 1 failure. The floor slab was found to be relatively thin at the section where the failure occurred and a crack had formed extending completely through the floor slab near the base of the wall.

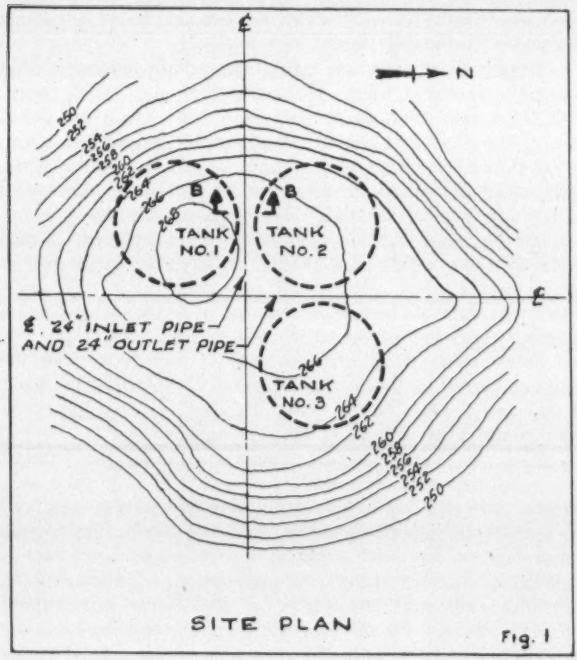


FIG. 1—ORIGINAL GROUND CONTOURS AND PROPOSED TANK ARRANGEMENT

The crack may have been formed by (1) shrinkage in the floor slab; (2) wall or floor settlement; or (3) wall movement resulting from varying water level in the tanks Water apparently had seeped through this crack for a long period as the wire-mesh reinforcement in the crack was almost completely deteri-

orated by rust. The water passing through the crack apparently gradually eroded fine material from the sand foundation.

There was a "Gunite rebound" slab formed over the pipe trench between tanks which failed and therefore leakage water did not rise to the ground surface. When sufficient fine material had been eroded to create a leakage channel for the water, the leakage velocity increased, causing more rapid erosion of the

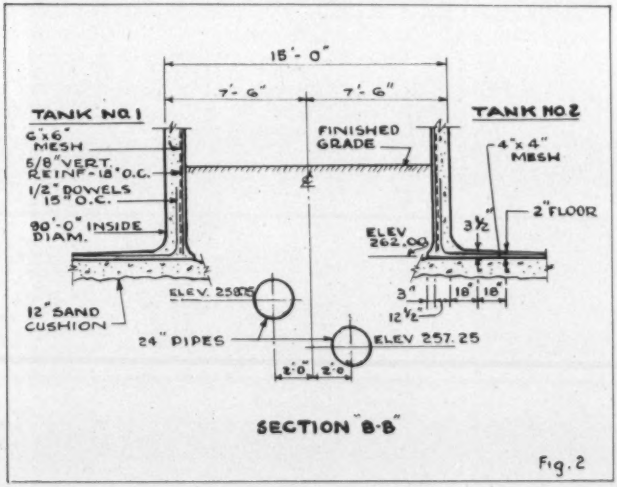


FIG. 2—CONSTRUCTION DETAIL AT POINT OF FAILURE

sand foundation which supported the tank floor slab. The final erosion must have occurred in a short space of time, causing sudden tank failure. Sudden failure is attributable to the fact that the roof collapsed because the tank's air vent capacity was inadequate to admit air fast enough to replace the volume of water leakage.

The failure of the second tank occurred in the same manner as the first tank, except that rapid erosion was caused by the

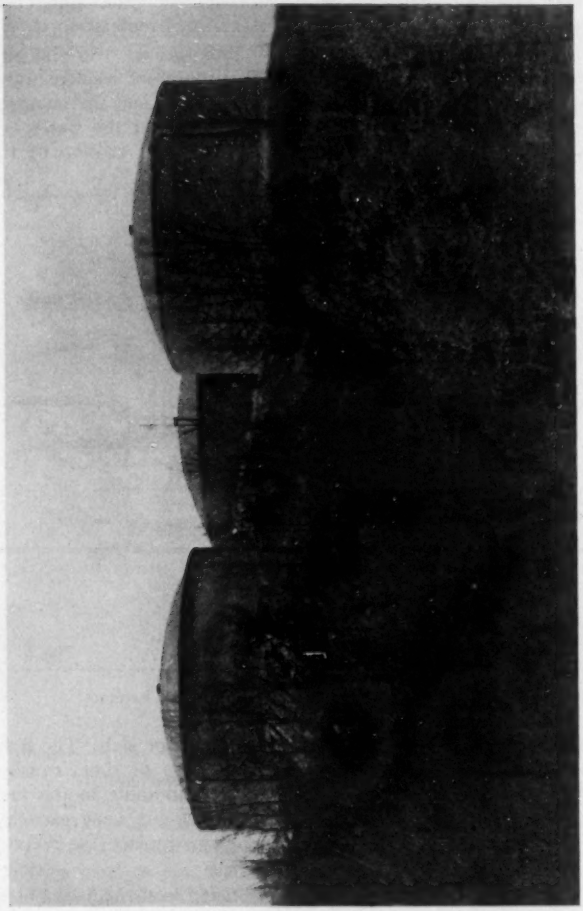


FIG. 3—THREE LAKE KONOMOC TANKS IN 1944, LOOKING NORTHWEST

wave of water from the first tank failure instead of slow erosion resulting from a crack in the tank floor slab.

Conclusion. The failure apparently was the result of an inadequate foundation design. It appears that if the sand foundation had been confined by a ring wall, sealed on ledge or undisturbed ground, the failure would not have occurred. An adequate ring wall would confine the sand foundation and

FIG. 4—INSIDE TANK NO. 2—LOOKING AT CRACK WHICH TRIGGERED FAILURE

prevent its being carried away by leakage. It also appears that the design of large-diameter "above ground" tanks should provide flexibility for inward wall movement resulting from prestressing and outward wall movement due to the effect of water in storage.

Inspection of the walls of the tanks after the failure indicated that they were adequately designed. There is some evidence of "leaching" and leakage but nothing of a serious nature.

The dome roof failed because of the unbalanced pressure created by the sudden loss of water. Inspection of the roof on the remaining tank indicates that it is in good condition except for a small area of spalling. The area of spalling can be repaired easily by waterproofing with Gunite or hot asphalt.

Except for the deterioration of the wire-mesh reinforcement in the flood-slab crack, which was seriously rusted, there was no other evidence of deterioration of the steel reinforcement. Even the wire-mesh reinforcement in the floor slab, which did not have adequate Gunite encasement, was found to be in good condition.

ANALYZING WATER SYSTEMS WITH THE McILROY FLUID NETWORK ANALYZER

BY ROBERT C. MOORE*

[*Read March 16, 1961.*]

Introduction

Fluid network analysis can be defined as the study of pressures and flows in fluid networks, such as water or gas distribution systems.

A network analysis is usually more than the solution of a single problem, and generally consists of a series of studies conducted under various conditions and alterations. Computing pressures and flows in a water distribution system by solving a flow equation for each pipe and satisfying Kirchoff's two basic laws by hand calculations is at best a tedious, repetitious, and seemingly endless task. The number of computations required to analyze even a small system is enough to discourage most engineers.

To further complicate the problem, most water systems have been constructed over a long period of time and are subject to one or more of the following conditions:

1. The piping in many systems was designed and installed for loading conditions which have not existed for many years. Some customers have changed locations, and others have drastically altered their demands for water
2. Records of data such as pipe locations, lengths, diameters and interconnections, have been kept with only questionable accuracy or have not been kept at all.
3. The internal condition of many pipes is unknown because of varying rates of tuberculation and accumulation of foreign material.
4. The condition and adjustment of valves and other pieces of equipment in the system are sometimes unknown after years of operation by all types of personnel.

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In view of the problems confronting him, probably every water-works engineer has wished at least once for a working model of his water system. With this model he could study system behavior under all kinds of loading conditions and try any alterations he desired. He could project into the future and learn what he might do today to best meet the needs of tomorrow. He could do these things and many more, if he had a working model of his system.

Background

A fulfillment of the engineer's wish was begun in 1946 by Malcolm S. McIlroy who was serving as assistant director of the M.I.T. Radar School in Cambridge. Dr. McIlroy set out to develop a direct electrical analogy of a fluid distribution system as the subject for his doctorate thesis at M.I.T. He was encouraged and aided in this effort by a number of New England waterworks men, including Thomas R. Camp, who conceived the original idea for devising an electric pipeline-network analyzer. In his thesis Dr. McIlroy also acknowledged with grateful appreciation the encouragement and contributions of S. C. Beane of Weymouth, R. W. Esty of Danvers, C. B. Hardy of Worcester, T. E. Kennedy of Fitchburg, A. C. King of Taunton, R. G. Oakman of Needham, and C. M. Saville of Hartford.

In 1947 Dr. McIlroy worked with engineers from the Standard Electric Time Company of Springfield, Mass., in developing a full-size network analyzer. This analyzer was installed in Dr. McIlroy's office at Cornell University in Ithaca, New York, where he was serving as a professor of electrical engineering.

One of the earlier analyses performed on the analyzer at Cornell was a study of the campus water distribution system conducted by R. H. Ellis, then with the Associated Factory Mutual Fire Insurance Companies of Boston and now an engineer with the firm of Metcalf & Eddy.

Several members may recall hearing Dr. McIlroy's presentation of a paper to the New England Water Works Association on November 16, 1950. In that same year he received the

John M. Goodell Prize, awarded by the American Water Works Association for a paper presented to that organization.

Description of the McIlroy Analyzer

The McIlroy Analyzer makes a direct analogy between certain electrical and hydraulic characteristics. It can rightfully be called an analogue computer and has often been described as a network simulator. A few men have referred to the analyzer as an "Electrical Slide Rule" and an "Electronic Brain." The latter title is particularly inappropriate, since the analyzer is not fundamentally electronic in nature and does not perform any brainlike functions. All of the brain power required to conduct a network analysis must be provided by the engineers who use the McIlroy Analyzer.

In the electrical analogy of a fluid distribution system, water flow is represented by a flow of electricity, and frictional pressure loss is represented by a loss of voltage. Stated conversely, voltage represents pressure, and current represents flow rate.

The three basic elements in any water system are the sources, pipe sections, and loads. Sources of water, such as pumps and reservoirs, operating at various pressures and discharge rates are represented on a McIlroy Analyzer by electrical sources, such as generators or rectifiers, operating at various voltages and currents.

The pipe sections in a system are represented on the analyzer by special electrical resistors called Fluistors*, which are interconnected in the same way that the pipe sections are interconnected in the system.

The loads or customers in a system are represented on the analyzer by electronic load units which draw current from the Fluistor network in the same way that customers draw water from the system.

When the analyzer has been properly connected and is operating at the desired level of voltage and current, the pressure and flow rate at any point in the system can be read directly from analyzer meters.

*Registered trade mark.

Data Required for an Analysis

While every system is unique in its layout and content, the basic data required for most analyses include:

(a) A system map showing the location, diameter, C number, and interconnection of every principal pipe in the system.
(b) A tabulation of loads including their location and flow rates.
(c) A list of sources, including their location, input pressure, and flow rate. Generally either the pressure or the flow rate of a source is only an estimated quantity.
(d) The values of any pressures or flow rates recorded in the system under one of the conditions to be represented on the analyzer. These data are used as a check on the accuracy of system representation.
(e) The elevation of every point in the system at which pressure is to be measured.
(f) An accurate and clear statement of each problem or alternative to be represented on the analyzer.

Specially prepared forms are used to convert basic system data into analyzer terms and to set up the analyzer to represent a particular system.

Size of Analysis

The number of pipes, loads, and sources which a particular McIlroy Analyzer can represent depends upon the analyzer's working capacity and the way in which it is used. The analyzer at Tufts University can represent up to 500 pipes, 225 loads and 36 sources. The analyzer at Western New England College in Springfield can represent 440 pipes, 180 loads, and 12 sources (see Fig. 1).

General Use of the McIlroy Analyzer

The first analysis of any system is a check on system representation by the analyzer. The accuracy to which known pressures and flows are duplicated by the analyzer is a measure of both the engineer's knowledge of system conditions and the analyzer's ability to represent these conditions. The analysis is *not* a measure of the engineer's ability. All engineers are

FIG. 1—MCILROY FLUID NETWORK ANALYZER INSTALLED AT WESTERN NEW ENGLAND COLLEGE, SPRINGFIELD, MASS. (Designed and Produced by the Standard Electric Time Company, Springfield, Mass.)

limited by the accuracy and amount of data which they are allowed to obtain and by the tools with which they are allowed to work. If requests for engineering material such as recording pressure gages and flow meters, water waste surveys, pipe coefficient measurements, and up dating of maps have been refused or not otherwise provided, the engineer can hardly be expected to know very much about his system.

In addition to revealing any need for more and better data, the first analysis also reveals the bottlenecks or weak links in a system. Some bottlenecks can be pinpointed without analyzing the system, but a few new ones are usually discovered in every analysis.

The second analysis of a system is usually a study of the effect of future loading conditions on present facilities. This analysis serves as a guide to the engineer in deciding how to eliminate existing bottlenecks and to strengthen the system for the future.

Subsequent analyses are generally studies of alternate loading and operating conditions. New pipes, pumps, customers, interconnections, and various combinations of these elements can be represented in any way the engineer may desire.

Specific Uses of the McIlroy Analyzer

During a five-day analysis conducted on a McIlroy Analyzer, the water department engineers in one of our larger cities discovered that the planned installation of a $500,000 pipeline could be delayed for at least 10 years. The interest required to make a capital expenditure of this magnitude represented a considerable saving to the city.

In the same analysis the need for a $10,000,000 pipeline was also revealed. This pipe was not required for 20 years, but its installation seemed mandatory after numerous other alternate solutions were tried without success. It is interesting to note that, when the engineers began the analysis, they had absolutely no idea this particular pipeline would be required.

Another recent analysis involved the study of a thirty-year-old system serving the cooling-water requirements of an oil refinery. The only things known about the system when the analysis began were the original lengths and diameters of most

of the pipe sections, an approximate idea of water consumption based on the requirements of heat exchangers, and a few readings of pressure taken in the system during an off-year peak period. Changes in system piping made during thirty years of operation, unknown amounts of tuberculation and accumulation of foreign material collected in pipes with low velocity flow, and a number of proposed new installations of pipes and loads all combined to make the analysis quite interesting. A number of combinations of pipes and loadings had to be tried before the measured pressures were duplicated. While the condition of several of the pipes were surprising to the system engineer, he accepted the results and studied the effects of future loading on the system. Subsequent field measurements, made since the analysis, have revealed that the analyzer had yielded accurate results.

One large water department, which owns a McIlroy Analyzer, claims it saved the cost of its analyzer the first time such equipment was used. A new main was designated to be 36-inch pipe on the basis of hand calculations and the best estimates available. After analyzing the system on a McIlroy Analyzer, a main no larger than 24 inches could be justified, even under the heaviest future loading imposed by the engineers. The difference in cost between the 36- and 24-inch installations was estimated to be in excess of $44,000, the price of the McIlroy Analyzer later purchased by this utility.

Another utility was recently faced with the problem of providing service to a large new industrial customer, located in an area which had low pressure during peak periods. The utility was prepared to spend a considerable amount of money to extend a high-pressure line into the area but decided first to study the system on a McIlroy Analyzer. A two-day study revealed a method of making three relatively small changes in existing piping and accomplishing all that the major pipe extension would have achieved. The method discovered by using the analyzer cost $20,000 less than the method previously decided upon.

Confronting almost every utility are the problems of making temporary installations during the cleaning and repairing of pipelines or the construction of roads and bridges. Recently one utility was prepared to install a temporary line across a long bridge during the construction of a complex traffic rotary. After

studying the system on a McIlroy Analyzer, an alternate method was discovered which proved to be cheaper and better than the bridge line. Similar analyses have been made by many utilities and have often resulted in permanent improvements to the systems.

Conclusion

A total of eighteen McIlroy analyzers have been designed and produced by the Standard Electric Time Company, the sole manufacturer of this equipment. Four of the analyzers are owned by water utilities: namely, the City of Baltimore Water Department, the City of Philadelphia Water Dept., the Washington Suburban Sanitary Commission, and the Baltimore County Water Dept.

Generally the best way to evaluate a product is to use it. The McIlroy Analyzer is certainly no exception to this rule. Analyzers are available for use on a consulting basis at Cornell University in Ithaca, N.Y., Midwest Research Institute in Kansas City, Mo., Tufts University in Medford, and Western New England College in Springfield. Details about the fees and availability of these machines can be obtained by writing the institutions which own them.

OVER A CENTURY OF SERVICE TO THE PEOPLE OF NASHUA

BY DONALD C. CALDERWOOD*

[*Read May 18, 1961.*]

Nashua, N. H., is a hustling New England city with a population of 40,000, which borders on the State of Massachusetts and possesses the characteristics of both states. It is called the "Gate City of New Hampshire," which is no idle boast, as its location in the southern part of the state makes it a natural place of entrance. It lies on the west side of the Merrimack River and is bisected by the Nashua River, which joins the Merrimack within the city limits. Since colonial times it has occupied a strategic location for transportation, commerce, and industry.

In the early colonial times it served as a trading post, but with the available water power, industry obtained an early start with the development of the cotton textile industry in the early 1800's. Until World War II textiles were the largest single employer of labor, but unlike many communities it was not a one-industry town, as its industry was widely diversified. This diversification has greatly assisted in the stable steady growth of the city, and figures recently released by the New Hampshire State Planning and Development Commission indicate that since 1950 it has been the fastest-growing city in the state.

Early History

In 1852, when the population was about 6,000, one year before Nashua became a city, and approximately twenty years before any other city in the entire Merrimack Valley (although they had much larger populations) had faced the problem of developing a municipal water supply, the men of Nashua and Nashville, as that part of the city north of the Nashua River was called, associated themselves together and formed a company, the purpose of which was to secure for the two towns an adequate supply of water. A charter was received from the State Legisla-

*President, Pennichuck Water Works, Nashua, N. H.

ture on June 19, 1852, and the first annual stockholders' meeting was held in May, 1853.

Once the company was formed and Directors were elected, months of study and time-consuming effort faced these individuals. A municipal water-supply system was a new type of enterprise, and consulting engineers, standards, etc., as we know today were non-existent. One committee was charged with the problem "to ascertain what encouragement would be offered by the citizens and corporations for the prosecution of the aqueduct enterprise"; another committee was instructed to acquire a drainage area from which water could be obtained. After much study and thought given to investigating the various watersheds in and about Nashua, the waters of Pennichuck Brook and its tributaries were selected as being of the best quality and of sufficient quantity to meet the requirements of a water-supply system. This was in 1853, and the name of the Company was, at the same time, changed to Pennichuck Water Works, after the brook from which the water was to be taken. Also, quoting from the records, a committee was chosen "to make investigations as to the best material for packing (caulking) pipe," and a committee of three "was appointed to determine the form and length of the socket (bell) of the pipe." These quotations serve to show the magnitude of the problems faced by these pioneers.

The first water supplied was drawn from a pond formed in 1854 by building a dam across Pennichuck Brook, just west of the Concord Road. This dam, which was intended to raise the water about twenty feet, was built of gravel and was probably of light construction, as it washed out with the high water of 1866. A stone dam was erected in its place, and it is still in use. As time went on other dams were built along the valley, and an immense volume of water was impounded.

The original pumping station was built in 1854. It was a wooden structure and housed a water turbine-driven pump, made at the Lowell Machine Shop. This company, afterwards known as the Saco-Lowell Shops, was later to receive world-wide fame as a builder of textile machinery.

In 1865, a very dry year, the quantity of water in the brook proved insufficient to provide both power for pumping and a

supply for the city, so an engine and boiler were installed as an auxiliary unit, to use when the water in the stream was low.

Previous to the installation of the engine and boiler a treadmill had been attached to the water pump, to supplement the power from the brook. This treadmill was operated by a horse, which, tiring of the work, was inclined to shirk. Therefore, in order that there should be no interruption in the service, the engineer at the time, a Mr. French, rigged up what was known locally as "French's Spanker." This spanker consisted of a stick or board, so arranged that at a certain number of revolutions of the pump the stick would descend upon the back of old Dobbin, urging him to greater effort.

At the time of the original water-works construction in 1854, a small distribution reservoir of 600,000 gallons capacity was built on Winter Hill, where the present one is located. It was torn down in 1885, and one of stone, circular in form and holding 4,000,000 gallons, was built in its place. This reservoir was in constant use until 1941, when a steel reservoir of 2,800,000 gallons capacity was erected, to give additional pressure on the distribution system. The old reservoir is now held substantially full of water for standby use.

The original estimate for the distribution system called for 600 feet of 14″, 2,800 feet of 12″, 2,000 feet of 10″, 8,200 feet of 8″, 4,500 feet of 6″ and 1,400 feet of 4″ cast-iron pipe. In the 1850's Nashua was one of the leading iron and steel centers of the country, and the order for the pipe was placed with a local foundry. A part of this pipe is still in use, giving satisfactory service even by today's standards. This pipe was cast in horizontal moulds and had a nine-foot laying length. The metal thickness corresponds with that of the present-day Class "A" pipe, which is recommended for 42 psi working pressure. For years the operating pressure on some of this original pipe has been 65-70 psi. The original plans for laying this pipe called for an 8″ line from the pumping station across country to the reservoir —about 5,700 feet—with 10″ and 12″ lines from the reservoir across the Nashua River into the business center of the city.

Twenty-five hydrants were put in with the initial installation of pipe. The first water rents were collected in October, 1855.

The problem of laying this pipe across the river aroused

much interest. Living in Nashua at the time was a teacher of mathematics, who, when consulted, advanced the theory that if an 11-inch "Boiler Iron Pipe 5/16" thick" was laid so as to be slightly arched in the center, it would with the aid of a few lateral wind braces, remain suspended after the water, under pressure, was in the pipe. When the time came for the opening of the gate and the filling of the pipe, a large gathering of people was on hand to see if the theory was sound. The pipe, needless to say, found a resting place on the bottom of the river.

After this disastrous episode the Directors engaged a bridge builder to build a trestle across the river to support the pipe.

The foregoing gives in brief what was done by the founders of the Pennichuck Water Works, facing a project largely new, and one whose financial returns were problematical. Since their time, many improvements have been made, and much of the plant has been rebuilt. These small beginnings were the foundation stones for the present system, and much credit is due the pioneers for their efforts.

The Present Water Works

The Pennichuck Water Works controls practically the entire water privileges of Pennichuck Brook and its tributaries with a total watershed area of 25.36 square miles. It has surface holdings of over 2,400 acres, 287 of which are water. This marginal land was acquired from time to time for the purpose of protecting the supply from pollution. In order to derive some revenue from the land which otherwise would be unproductive, the area has been largely seeded or planted to white pine. The growth of this pine was remarkable, but the hurricane of September, 1938, destroyed in a few hours that which took nature years to produce. After the hurricane nearly five million board feet of logs were salvaged and sold. Our forest areas still have many mature trees, and most of the scars of the hurricane are now shielded from view by an excellent growth of young pine. Formerly most of the forestry work was performed by employees during the winter months. For the past few years we have been doing considerable forestry improvement work under the Agricultural Conservation Program of the U.S. Dept. of Agriculture. Under this program the federal government shares the cost (from 50% to 75%) for

specific conservation practices. This work has been done by contract under the direction of a professional forester.

Most of the domestic and commercial water supply is obtained from springs and flowing wells. This water is collected in a storage basin, called the Supply Pond, having a capacity of 56 MG, from which it is pumped either to the distribution reservoir or to the mains. The approximate daily yield from these springs and wells is 3.5 MG.

For many years these springs and flowing wells supplied all the water used in the city. However, the consumption has so increased since World War II that during the hot, dry summer season the surface water stored in three ponds upstream from the Supply Pond is used to supplement the yield from the springs. These ponds impound 650 MG of excellent quality water.

The surface water from the valley, to prevent its mingling with that from the wells, is diverted around the storage basin through a 72-inch penstock. This penstock provides a waste-way for the excess water from the valley, and the water passing through it is utilized, as needed, to furnish power for the Dean & Main water-power pump.

To insure reliability, several kinds of power are used to drive the various pumping units, which are housed in three separate brick buildings. The pump mostly used is a 6-MGD horizontal duplex plunger-type pump, specially designed by Dean & Main. The power for this pump is obtained from water passing through the 72-inch penstock under a 57-foot head, driving a 300-hp water wheel at a rate of 400 revolutions a minute. This wheel in turn drives a 16-foot fly-wheel, attached to a drive shaft turning at the rate of 100 revolutions a minute, and the power is then transmitted to the pump by a chain drive. During the past ten years this unit has pumped approximately 58% of the water used. Obviously, this pumping unit is used at all times when the run-off in the valley is sufficient to provide the needed power.

In the easterly wing of the so-called Snow Station is housed a centrifugal pump, driven by a 250-horsepower diesel engine. This unit, installed in 1934, has a capacity of 5.8 MGD. In the westerly wing of this same building are housed two electrically driven centrifugal pumps that were installed in 1949. These are

identical units, each having a capacity of 4.5 MGD when operating individually, or 8.4 MGD when operated in parallel. These electrically driven pumps are located in the wing that formerly housed the steam pumping unit, that was installed in 1893.

At the outbreak of World War II, before the electrically driven pumps were installed, two centrifugal pumps, driven by gasoline engines, were installed in the old Worthington Station. These were for emergency use only and have a combined capacity of 3.5 MGD.

The suction lines and piping are so arranged that any of the pumping units can be operated in parallel.

There are two trunk lines into and through the city, a 16-inch and a 24-inch main. The system is elongated north and south, which makes it difficult, because of the river, brooks, and railroads, for ideal gridironing. The mains consist of 115 miles of cast-iron pipe, ranging in size from 4 to 24 inches, and 9 miles of mains less than 4 inches in diameter. About 1930 the company established a policy of 8″ as the minimum size for cast-iron distribution mains. There are 8,124 services in use. All commercial and industrial services are metered, but we still have about 1,800 domestic customers on the so-called flat or fixture rate. For several years meters have been placed on all new services or where there is a change of ownership of an unmetered property. This approach softens the financial impact of a crash metering program and in the end will accomplish the same result.

We are very much gratified that the National Board of Fire Underwriters after their survey last year rated our water-supply system as Class I.

In common with growing communities, the increase in the number of customers, the opening of new areas for development, and the new uses for water, such as air-conditioning, garbage disposals, and different industrial processes, have given us our troubles too. Basically, we were very fortunate that through the years the management of the system was very far-sighted and built in reserve or excess capacity. Because of this foresight we have not been subjected to all the problems and expense experienced by some communities. In order to keep ahead of the situation, we are constantly making engineering studies in an attempt to determine both the immediate and long-term needs of

our system. Many of the projects connected with a water-supply system must be anticipated and planned, and construction started years ahead, in order to prevent shortages and the imposition of restrictive measures. To date we have never had to restrict the use of water.

As a result of these studies, in 1958 we constructed a steel distribution reservoir at the southerly side of the city. This reservoir is 160 feet in diameter and has a capacity of 5 million gallons. The remarkable thing about this reservoir is the short time it took to have it become a part of our system. At the Directors' meeting on February 3, 1958, it was voted to proceed with the erection of the reservoir, provided that the required permission could be obtained from the New Hampshire Public Utilities Commission and the financing arranged. It took the rest of the month to arrange these details, and contracts were signed for 16″ and 24″ pipe, fittings, foundations, and steel work about March 1st. Because deep snow still covered the ground, the actual construction was delayed until the last week in March. More than 1,500 cubic yards of ledge had to be removed in the preparation of the foundations, and ledge was encountered for practically the entire distance in the construction of the 16″ and 24″ connecting pipelines. All the steel work and pipelines were completed, and the reservoir was filled with water for testing on June 12. Three and one-half months from the placing of the first order the project was completed, except for the painting. The total completed cost was nearly one-quarter million dollars. How times and conditions change—one year earlier the best delivery that could have been obtained on the steel alone would have been 18 to 24 months. An example of the far-sightedness of the management:—the site for this reservoir was purchased 50 years before.

To build reservoirs and miles of pipelines, and install pumping units, services, meters, etc., takes money—lots of it. Some of this money came from retained earnings and depreciation charges, but most of it was obtained from long-term borrowing from insurance companies. In the last few years we have borrowed over a million dollars to pay for this required expansion program. Our next major financing will have to be in the form of equity capital.

In times of inflation, increased operating costs and large additions to plant go hand-in-hand with rate problems. For many years any change in the water rates was accomplished by a percentage increase across the board. Through the years this resulted in inequities. Therefore, in 1957 we made a complete accounting analysis and cost-of-service study, after which we developed an entirely new set of rates, based on these studies. This new rate schedule, by lowering the allowable use under the minimum rate, resulted, percentagewise, in a rather substantial increase for the smaller users (1,500 to 4,500 cu. ft.); but for those using between 7,000 and 250,000 cu. ft. per quarter there was a decrease. There was also an increase for those using over 250,000 cu. ft. a quarter. After many conferences and the filing of reams of supporting data the New Hampshire Public Utilities Commission finally allowed these new rates to go into effect.

In common with most changes they resulted in some complaints, but by having adequate publicity we feel these complaints were held to a minimum.

The Pennichuck Water Works is the largest privately owned water company, and one of the few left, in the state. Periodically some individual or minority group brings up the question of public ownership. So far, the more stable minds have prevailed, and to date these proposals have not been backed by a number substantial enough to bring this change about. The management has always operated on the policy of "what is the best for Nashua?", and this procedure through the years has built up a deep-seated good will, which is hard to break down.

The Company is owned by approximately 300 stockholders, most of whom are Nashua residents or have Nashua connections.

There are 25 employees, and except for a few of the larger construction projects, the company has done all its own construction and maintenance work. Employee relations have always been excellent with practically no turnover. At the present time the average for the entire work force is 15 years of service. These employees and their predecessors have successfully maintained service through conflagration, hurricane, and flood. They will endeavor to keep this enviable record intact.

In Nashua you don't ask for a drink of water—you ask for a drink of Pennichuck.

THE FIRST FOURTEEN YEARS

BY CLARENCE W. METCALF*

[*Read May 18, 1961.*]

On July 1, 1961, the New Hampshire Water Pollution Commission will have its fourteenth anniversary.

Back in 1947, the State Legislature established this agency with a Commission made up of ten members representing various State departments, divisions or commissions, private industry and water works. At the same time, it was determined that the director of the Division of Sanitary Engineering of the State Department of Health should act as Technical Secretary, without voting powers or privileges.

Under the original Act, the Commission was given the power and authority: to study and investigate all problems connected with the pollution of the surface waters of the State; to conduct scientific investigations and research on the elimination of various types of pollution; to cooperate with other agencies; to perform all necessary work relative to classification (we will take this up in more detail a little later); to require filing of plans and specifications for treatment plants; to investigate and approve applications for State and Federal aid; to work with other states on pollution of interstate waters, and to employ personnel and purchase necessary equipment. This brief listing of powers and duties is presented only to point out the magnitude of the Commission's job, and with the expansion of construction grants and classification, the program has snowballed.

To carry out the Commission's program, it has been necessary over the years to build up a staff consisting of engineers, chemists, biologists, technicians and administrative personnel. As you are well aware, the work associated with planned classification of an area involves: hundreds of hours in the field; a sampling program spread out over months or years, to give the most accurate picture possible of present conditions; an impartial

*Director of Municipal Services and Administration, New Hampshire Water Pollution Commission, Concord, N. H.

study which will provide the Commission with evidence upon which it can determine the most desirable classification considering such factors as public health, industrial development, economic growth, geographical features and social influences; plus countless hours of work necessary to pull the many phases of the study together into report form. All this and more is part of the classification job alone, and the thirteen full-time employees of the Water Pollution Commission must still find time to spend on enforcement and on special studies, such as flotation, decolorization, chlorination and the control of aquatic nuisances, to mention a few.

Rather than go into detail on the various statutes which come within the scope of Commission administration, I would prefer to place emphasis on the classification program, and how it has developed over the past fourteen years. Just to give us a little information on standards used in classifying, we will run down through the various classes or grades of surface waters. The highest of these, A, is potentially acceptable for drinking, after disinfection; B-1, the next category, has limits of 240 coliform bacteria per 100 milliliters and may also be used for drinking after adequate treatment; B-2 has a limit of 1,000 coliform bacteria per 100 ml. and is acceptable for drinking after adequate treatment, but not for bathing as is the case of A and B-1; C, the next quality, is suitable for boating, fishing and industrial use; while the last category, D, shall be considered as being devoted primarily to the transportation of sewage or industrial wastes, or both, without nuisance.

Now, what progress has been shown to date in the classifying of surface waters? Up to the middle of March, 1961, the surface waters classified in New Hampshire amounted to approximately 8,800 miles of stream, or about 55% of the 16,000-mile total. Within a few days, the Piscataqua River Watershed with an area of 640 square miles was added, and the 1,200 miles of stream in New Hampshire's portion of the 'shed rounds out the figure to 10,000 miles of classified streams. Of the 9,300 square miles of area in the State, better than 65% is now drained by classified waters, with over 90% of these waters in the B-1 category.

I believe we should point out right here that some of the most difficult work in the area of classification lies ahead. Al-

though we can point to impressive figures, we need only one look at a New Hampshire map of Classified Waters to see that our largest river systems still remain unclassified. With the Merrimack, Connecticut, Androscoggin, Ammonoosuc and several other large streams waiting for classification, there is still plenty of work to be done. But as we look back fourteen years, it becomes increasingly apparent that a tremendous amount has been accomplished in this span of time. For instance, prior to 1947 the sewage treatment plant was practically unheard of in New Hampshire, but since that time sixteen towns and cities have put close to $12,500,000 into facilities to abate pollution. In addition, there is a gradual increase in voluntary interest in pollution control, brought about, at least in some instances, by a very realistic recognition of what this means in dollars and cents to the municipality.

Directly tied in with the Commission's long-range program of classification is State and Federal assistance for the abatement of pollution. In preparing legislation for State grants, the Commission felt that municipalities which had put in systems subsequent to July 1, 1947, but prior to enactment of the State-Aid program, should be allowed assistance in the form of retroactive grants, equal to 20% of eligible construction costs. This legislation provided for retroactive payments, spaced over a period of 20 years, without interest. Thirteen New Hampshire municipalities qualified for these payments, and in the next twenty years the State will pay out in excess of $610,000.00.

In preparing legislation for State Construction grants on current projects, the provisions of Public Law 660 (the Federal program) were closely followed, especially in determining those construction costs eligible for grants. There are two important exceptions to the Federal law which allows a maximum for each project of $250,000 or 30%, whichever is the lesser. The first of these exceptions is a 20% State grant *with no dollar ceiling*, and the second is the payment of interest on the grant at the same rate as the municipality is paying for the amortization of its bond issue. Reimbursement is made to eligible communities over the life of the bond issue, and we have found that the 20% no-ceiling grant, plus interest, often amounts to more than the 30% of Federal aid. Up to the present time, five towns and

cities have become eligible for State aid under the current program, and they will receive a total of about $560,000, principal and interest, over the life of their bond issues. As an added incentive to construction, the State originally authorized a guarantee of bonds for the construction of water-pollution abatement works up to $10,000,000. This figure has recently been increased to $15,000,000. In addition, debts incurred by municipalities in constructing treatment works, whether the project is voluntary or involuntary, are not to be included in the net indebtedness of the municipality.

Now what do we see for the future? With confidence, it can be predicted that the next ten years will see more construction on sewage treatment works than the total of all preceding years. To bear out this statement we point to the fact that right now, fourteen municipalities are doing studies on sewerage systems, and the recent classification of the Piscataqua River Watershed will, by itself, push this number up to twenty or more. If we include the classifying of our two great interstate river systems, the Connecticut and Merrimack, and plan for the allocation of Federal grants, we find that every nickel of these funds will be ear-marked for at least the next ten years, even if the proposed accelerated program goes into effect.

In conclusion, I would like to point again to what, in my opinion, is one of the greatest steps forward in the control of water pollution, and this is the gradual recognition by people throughout the fifty states that it is decidedly to their advantage to act voluntarily. The old philosophy, so long accepted by the public, that action should be deferred on health measures until force is applied by law, is being slowly replaced by this desire to look honestly at the future and take action.

PROCEEDINGS

March 1961 Meeting

Tufts University, Medford, Mass.

March 16, 1961

A meeting of the New England Water Works Association was held at Tufts University, Medford, Mass., on Thursday, March 16, 1961, with 235 members and guests in attendance.

"Morning Coffee" was served in the Alumni Lounge, after which the group assembled in Cohen Auditorium. This session was opened by the late President Kenneth W. Robie,* who stated that it promised to be a unique meeting in that it was to be devoted entirely to the matter of water-distribution systems. Accordingly, Dr. Donald R. F. Harleman, Director of the Water Works School, had as his subject "Hydraulics of Water Distribution Systems."

Following the Water Works School, a paper entitled "The McIlroy Fluid Network Analyzer" was presented by Robert C. Moore, Director of the Computer Center, Western New England College, Springfield, Mass.

Luncheon was served in the Jackson Gymnasium with President Robie introducing those at the head table. Ashley S. Campbell, Dean of the College of Engineering, was most cordial in his remarks of welcome to the group and issued an invitation for a return visit to the University.

President Robie announced that in accordance with Article VII of the Constitution, the Association is directed to elect a nominating committee at the March meeting. On a motion made by Richard H. Ellis and duly seconded, the following were elected to serve as the Nominating Committee for the ensuing year: William B. Duffy, Roger G. Oakman, Allan F. McAlary,

* Deceased August 18, 1961.

Edward L. Tracy and George G. Bogren, with Mr. Tracy as Chairman.

In presenting the NEWWA Scholarship Award, Chairman William B. Duffy said: "The New England Water Works Association Scholarship program was adopted in May, 1956, to promote the advancement of water-works practice through the members of the Association. The contributions of members to the Scholarship Fund made it possible to award the first scholarship grant from the interest on the fund in September, 1958, to Frank A. Wyskiel, a resident of Manchester, N. H., and a student at Cornell University, Ithaca, N. Y. I am happy to announce that Mr. Wyskiel has made a contribution to the Scholarship Fund and is at work in the water-works field. A second scholarship grant was made in November, 1959, to Allan Ferry, a resident of Manchester, N. H., and a student at the Massachusetts Institute of Technology.

"It is particularly appropriate that at this, the first meeting ever held by the NEWWA at Tufts University, the Scholarship Committee, consisting of Thomas R. Camp, William P. Melley, Roger W. Esty, Kenneth F. Knowlton, Richard M. Cleveland, Harry M. Wooster and William B. Duffy, is able to make another scholarship grant. The recipient, Robert B. Taylor, a native of Danbury, Conn., is a Junior Member of the Association and a member of the Class of 1961 at Tufts University. He will receive a degree in Civil Engineering this June and is to continue graduate studies in sanitary engineering at Harvard University. It is a great pleasure for me in behalf of the NEWWA to present to you, Robert, this scholarship grant of $300 and to wish you every success in your studies." Mr. Taylor replied, "I suppose that there is only one thing that I should say here, and that is 'thank you.' I hope that I am able to justify the faith you have shown in me by this award."

The activities of the day were concluded with conducted tours of several buildings of Tufts University.

April 1961 Meeting

The Hedges, New Britain, Conn.

April 20, 1961

New Britain, Conn., was the gathering place for the Southern New England meeting of the New England Water Works Association on Thursday, April 20, 1961. About 160 members and their guests met at New Britain's Filtration Plant on Shuttle Meadow Ave., where coffee and doughnuts were served prior to an inspection tour of the plant.

Following luncheon at The Hedges, the late President Kenneth W. Robie introduced those at the head table. Hon. Julius J. Krimski, Mayor of New Britain, brought most cordial greetings on behalf of that city. Chairman of the Board of Water Commissioners, Silvio A. Silverio, welcomed the group and extended a warm invitation for a return visit to that city by the Association.

A paper, "Water Department Highlights," was read by George W. Wood, Chief Engineer, Board of Water Commissioners, New Britain, Conn.

A paper, "Operational Procedure of New Britain Filtration Plant," was read by I. Laird Newell, President, Henry Souther Engineering Co., Hartford, Conn.

A paper, "New Filtration Plant," was read by George L. Burke of Robert A. Hurley & Associates, West Hartford, Conn.

May 1961 Meeting

Nashua, New Hampshire

May 18, 1961

The Northern New England meeting of the New England Water Works Association was held at Nashua, N. H., on Thursday, May 18, 1961, with 196 members and guests present.

The group met at the Pennichuck Water Works on Route 3, where coffee and doughnuts were served, and then proceeded

via a motorcade to The Nashua Corporation, where they were taken on guided tours of the plant, which was in full operation.

Luncheon was served at McNulty & Foley's, after which the late President Kenneth W. Robie introduced those at the head table.

The greetings of the city of Nashua were brought by the Mayor, Hon. Mario J. Vagge.

A paper on "Brief History of the Pennichuck Water Works" was read by Donald C. Calderwood, President and Manager of the Pennichuck Water Works, Nashua, N. H.

A paper on "Water Pollution Control in New Hampshire" was read by Clarence W. Metcalf, Director, Municipal Services and Administration, New Hampshire Water Pollution Control Commission, Concord, N. H.

A paper on "Nashua's Pollution Control Program" was read by Joseph C. Lawler, Partner, Camp, Dresser & McKee, Boston, Mass.

BOOK REVIEW

WATER SUPPLY: ECONOMICS, TECHNOLOGY, AND POLICY. *By Jack Hirshleifer, James C. De Haven, and Jerome W. Milliman.* 368 pp. Chicago, Ill.: The University of Chicago Press, 1960. $7.50.

The study of water supply resulting in this book was supported by The RAND Corporation of Santa Monica, Cal., a non-profit organization, as part of its program of research on problems of national interest.

The book itself emphasizes the economics of water supply for municipalities, agriculture and industry. The authors state that the purposes of the book are "to inform the general citizen about water supply and to provide instruction for the administrator and professional in the field as to the application of economic and technological knowledge to the solution of practical problems."

As an example of present-day water policies, the authors analyze in detail the New York water crisis of 1949-50 and the proposal for construction of the Cannonsville reservoir and aqueduct, on which construction was begun in 1955. The authors' study of this problem and the solution adopted leads them to the "judgment that water-supply decisions are typically made without proper economic analysis, this being true not only of small or backward municipalities but of our greatest cities."

The list of chapters is as follows:

1. The Water Problem.
2. Our Water Resources: The Present Picture.
3. The Economics of Utilization of Existing Water Supplies.
4. Criticisms of Market Allocations: The Political Allocation Process.
5. Municipal Water Rates.
6. Investment in Additional Water Supplies.
7. The Practical Logic of Investment Efficiency Calculations.
8. Technological Features and Costs of Alternative Supplies of Water.

9. Water Law: Government Discretion or Property Rights?
10. New York's "Water Crisis": Case Study of a Crucial Decision.
11. Water for Southern California: Case Study of an Arid Region.
12. Some Controversial Conclusions and Their Implications.

The book also contains 29 illustrations and a 10-page index. Copious footnotes throughout the book contain references to source material.

GEORGE C. HOUSER

WHAT PRICE WATER—SALT OR FRESH?*

Despite the current great excitement about desalting the sea, the price of water delivered to your kitchen tap is still only a fraction of the cost of fresh water from the sea at the desalting plant. On the basis of a valid cost comparison, even the cheapest desalted sea water is on the order of twenty times as expensive as fully treated fresh water. Thus, according to the American Water Works Association, it will be some time before desalted sea water can be considered an economical alternative to fresh water as the source of domestic water supply.

Actual desalting costs at the new Freeport, Tex., plant and other installations are reported to be approximately $1.00 per thousand gallons and up. There have been numerous claims of lower costs for as yet unproved techniques and devices, but the $1.00 figure is pretty generally accepted as the present goal for desalting. In the current enthusiasm about progress in the field of desalting, supporters have made much of the comparison between $1-per-thousand-gallon desalted water and fresh water at 20-70 cents per thousand gallons. But what they have been comparing is the cost of operating a desalting plant, without taking into account depreciation of the equipment or delivery of the water or the administrative expenses involved in its sale, with the price of public water supply at the tap at the highest unit rate.

The average cost of a thousand gallons of water to public water suppliers, as indicated by a recent American Water Works Association survey of 497 utilities in the United States, was 12.3 cents, but this figure included not only the cost of treatment, but that of distribution, depreciation of plant equipment, and administrative costs as well. The cost of treatment for fresh water, including softening, approximates 5 cents per thousand gallons. And this is the figure that is comparable with the $1.00 cost of desalting.

As the Association sees the desalinization program, current

* News bulletin from American Water Works Association, July 14, 1961.

research is of real importance as a means of preparing the nation for the future and, even more, as a means of benefiting some of the many water-short areas of the world. In the United States, however, total consumptive use of water at the present time is only about 10 per cent of the total fresh water supply economically available. Thus, except in most unusual circumstances, desalted water is of much less interest to public water suppliers than facilities—reservoirs, treatment plants, distribution mains—adequate to permit delivery of the water they now have to their customers without restriction.

RECENT PUBLICATIONS

"Evaporation Control Research, 1955-58." By Robert R. Cruse and G. Earl Harbeck, Jr. Geological Survey Water-Supply Paper 1480. (Prepared in collaboration with the Southwest Water Evaporation Research Council, the Southwest Research Institute, and the Texas Board of Water Engineers.) Washington, D. C.: U.S. Government Printing Office. 45 pp. Price 50 cents.

"Chemical and Physical Quality of Water Resources in Connecticut, 1955-1958 (Progress Report)." By F. H. Pauszek. Connecticut Water Resources Bulletin No. 1. Published by the Connecticut Water Resources Commission in cooperation with the Geological Survey, U.S. Dept. of Interior. 79 pp. This bulletin contains information on the chemical quality of surface waters in the Housatonic, Connecticut and Thames River basins. Copies can be obtained free of charge by writing to Mr. William S. Wise, Director, Connecticut Water Resources Commission, 650 Main St., Hartford, Conn.

LECTURES ON "WASTE WATER TREATMENT AND DISPOSAL"

Several years ago the Sanitary Section of the Boston Society of Civil Engineers conducted a Seminar on "Waste Water Treatment and Disposal." The Seminar consisted of twelve lectures by well-known sanitary engineers. The series proved to be so popular that the Sanitary Section decided to publish the lectures in the form of a paperback book. Two additional lectures on the "Hydraulics of Waste Water Treatment," by Thomas R. Camp, which were not part of the original Seminar, have been included in the published book.

The book contains the following chapters:

Introduction, by Abel Wolman, Professor, Johns Hopkins University

1. Concepts and Functional Outline of Treatment Processes, by Gordon M. Fair, Professor, Harvard University.
2. Fluid Mechanics Applied to Waste Treatment Problems, by Thomas R. Camp, Partner, Camp, Dresser & McKee.
3. Racks, Screens, Grit Chambers, Preaeration, Flocculation, Flotation, and Sedimentation, by Frank L. Flood, E. Sherman Chase and John S. Bethel, Partners, Metcalf & Eddy.
4. The Dissolved Oxygen Balance in Streams, by Harold A. Thomas, Professor, Harvard University.
5. Sewage Sludge Digestion, by R. S. Rankin, Consultant, Dorr-Oliver.
6. Chlorination of Sewage, by Rolf Eliassen, Professor, M.I.T.
7. Pumps, Measuring Devices, and Hydraulic Controls, by Allen J. Burdoin, Senior Engineer, Metcalf & Eddy.
8. Industrial Wastes, by Edward W. Moore, Professor, Harvard University.
9. Microbiology and Biochemistry of Waste Water Treatment, by Ross E. McKinney, Professor, M.I.T.
10. The Design of Trickling Filters and Activated Sludge, by Ross E. McKinney, Professor, M.I.T.
11. Hydraulic Problems of Ocean Disposal, by Frank L. Heaney, Senior Engineer, Fay, Spofford & Thorndike, Inc.
12. Water-Pollution Control Practice in an Expanding Economy, by Edward J. Cleary, Executive Director and Chief Engineer, ORSANCO.

13. Applied Hydraulic Design of Treatment Plants, Part One, by Thomas R. Camp, Partner, Camp, Dresser & McKee.
14. Applied Hydraulic Design of Treatment Plants, Part Two, by Thomas R. Camp, Partner, Camp, Dresser & McKee.

These lectures will be available about September 1, 1961. They are to be sold on a non-profit basis for $3.50 postpaid. Orders should be placed with the Boston Society of Civil Engineers, 20 Pemberton Square, Rm. 601, Boston 8, Massachusetts. Payment must accompany orders.

ERRATA

This standard should have been included in Vol. 75, No. 2, June, 1961, as listed in the table of contents for that issue.

AWWA C202–60T

American Water Works Association

TENTATIVE
AWWA STANDARD
for
MILL-TYPE STEEL WATER PIPE

This "Standard for Mill-Type Steel Water Pipe" is based upon the best known experience and is intended for use under normal conditions. It is not designed for unqualified use under all conditions, and the advisability of its use for any installation must be subjected to review by the engineer responsible.

First Edition approved Apr. 25, 1940; Second Edition approved as "Tentative" May 15, 1960.

AMERICAN WATER WORKS ASSOCIATION
Incorporated
2 Park Avenue, New York 16, N.Y.

Prepared by

Water Works Practice Committee 8310 D

Acknowledgment is made and appreciation is expressed to the Subcommittee on Pipe of the Steel Water Pipe Manufacturers Technical Advisory Committee for its assistance in the preparation of this standard. The officers of this committee are R. C. Beam, chairman; Walter H. Cates, secretary.

Latest Revisions to C202

This Second Edition of AWWA Standard C202 was approved as "Tentative" on May 15, 1960. The principal change involved is that this edition covers mill-type pipe in all sizes, whereas the First Edition covered both fabricated and mill-type pipe in sizes up to, but not including, 30 in.

Designation. As a result of the revision, the former designation, "C202–59," has been changed to "C202–60T."

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AWWA C202–60T

Tentative AWWA Standard for

Mill-Type Steel Water Pipe

Section 1—General

Sec. 1.1—Scope

This standard covers mill-type steel pipe intended for the conveyance of water. It covers pipe in all sizes; in single or double random lengths or specified laying lengths; in straight sections or other special sections required for closures, curves, or changes in alignment or grade to meet special conditions; and with ends prepared for the type of joint specified. For the purpose of this standard, mill-type pipe is defined as furnace-welded, electrically welded, or seamless steel pipe of any size produced to meet finished-pipe specifications. The types of pipe covered by this standard shall be limited by the following provisions:

1.1.1. *Furnace-welded pipe.* Furnace-welded pipe shall be continuous butt welded or furnace butt welded.

1.1.2. *Electrically welded pipe.* Electrically welded pipe shall be of Grade A, B, or X42,* as specified by the purchaser, and shall be induction butt welded; spiral- or straight-seam resistance butt welded; or spiral- or straight-seam fusion butt welded. Fusion-butt-welded pipe shall be manufactured by automatic submerged-arc or automatic shielded-arc welding.

1.1.3. *Seamless pipe.* Seamless pipe shall be of Grade A, B, or X42, as specified by the purchaser.

Sec. 1.2—Definitions

Under this standard, the following definitions shall apply:

1.2.1. *Purchaser:* The person, firm, corporation, or governmental subdivision entering into a contract or agreement for the purchase of any materials or work to be performed under this standard.

1.2.2. *Contractor:* The person, firm, or corporation executing the contract or agreement with the purchaser to furnish any material or perform any work.

1.2.3. *Inspector:* The duly authorized representative of the purchaser qualified by training and experience in the manufacture of steel pipe of the character covered by this standard.

1.2.4. *Bevel:* An angle applied on the end of a pipe and measured from a line perpendicular to the axis.

1.2.5. *Butt weld:* A weld whose throat lies in a plane disposed approximately 90 deg with respect to the surfaces of at least one of the parts joined.

* Grades A and B under this standard are similar to grades A and B for pipe under American Petroleum Institute API 5L (Specifications for Line Pipe). Grade X42 is similar to Grade X42 for pipe under API 5LX (Specifications for High-Test Line Pipe). The purchaser need not make reference to the API specifications in using this standard, however.

The size of a butt weld is expressed in terms of its net or unreinforced throat dimension in inches. A double-welded butt joint is one in which the filler metal is added to both sides. A single-welded butt joint is one in which the filler metal is added to one side only.

1.2.6. *Fillet weld:* A weld of approximately triangular cross section whose throat lies in a plane disposed approximately 45 deg with respect to the surfaces of the parts joined. The size of the fillet weld is expressed in terms of the width, in inches, of one of its adjacent fused legs, the shorter if unequal.

1.2.7. *Flame cutting:* The process of severing metal by means of a gas flame.

1.2.8. *Furnace-welded pipe:* Either bell-welded or continuously welded pipe.

1.2.9. *Bell-welded pipe:* Pipe produced in individual lengths from cut-length skelp, having its longitudinal butt joint forge welded by the mechanical pressure developed in drawing the furnace-heated skelp through a cone-shaped die (commonly known as a "welding bell") which serves as a combined forming and welding die.

1.2.10. *Continuous-welded pipe:* Pipe produced in continuous lengths from coiled skelp and subsequently cut into individual lengths, having its longitudinal butt joint forge welded by the mechanical pressure developed in rolling the hot-formed skelp through a set of round-pass welding rolls.

1.2.11. *Fusion welding:* The process of welding metals in the molten or molten and vaporous state, without the application of mechanical pressure or blows.

1.2.12. *Girth weld:* A circumferential welded seam lying in one plane, used to join sections into lengths of straight pipe or to join pieces of mitered pipe to form fabricated special sections and fittings.

1.2.13. *Grade or class of material:* The designation of material as to chemical analysis or physical properties.

1.2.14. *Ladle analysis:* The chemical analysis taken at the time the steel is cast into ingots.

1.2.15. *Manufacturing process:* The designation of pipe in accordance with the method of manufacture (see Sec. 1.1).

1.2.16. *Mill-type pipe:* Seamless, furnace-welded, electrically welded, or furnace-butt-welded steel pipe of any size produced to meet finished-pipe specifications.

1.2.17. *Nominal outside diameter:* The commercial name or given dimension for pipe in sizes up to 12 in., as distinguished from the actual or measured dimension.

1.2.18. *Nominal size:* The commercial name or given dimension for pipe in sizes up to 12 in., as distinguished from the actual or measured dimension.

1.2.19. *Nominal wall thickness:* The named or given thickness as distinguished from the actual or measured thickness.

1.2.20. *Nominal weight per foot* (for uncoated and unlined pipe): The theoretical weight per foot, as shown in published tables, as distinguished from the actual or measured weight per foot of the finished pipe.

1.2.21. *Plain-end pipe:* Pipe cut off to random or exact lengths, but not threaded. It is not beveled unless so specified.

1.2.22. *Resistance-butt-welded pipe:* Pipe having a longitudinal or spiral butt joint in which coalescence is produced by the heat obtained from re-

sistance of the pipe to the flow of electric current in a circuit of which the pipe is a part, and by the application of pressure.

1.2.23. *Root:* The zone at the bottom of the cross-sectional space provided to contain the deposited filler metal.

1.2.24. *Seamless pipe:* Pipe without welds made from solid ingots, blooms, billets, or round bars which have been hot pierced and then brought to the desired size by hot rolling, hot drawing, or a combination of both.

1.2.25. *Specified lengths:* Sections of finished pipe whose length dimensions do not vary from a fixed figure specified by the purchaser by more than the tolerance set forth in this standard.

1.2.26. *Spiral-seam fusion-welded pipe:* Pipe in which the line of the fusion seam forms a helix on the barrel of the pipe.

1.2.27. *Straight-seam fusion-welded pipe:* Pipe in which the line of the fusion seam parallels the axis of the pipe.

1.2.28. *Throat:* The thickness of deposited weld metal, not including reinforcing, along a straight line passing through the root.

1.2.29. *Handling-tight coupling:* A threaded coupling sufficiently tight that a wrench is necessary to loosen it.

1.2.30. *Power-tight coupling:* A threaded coupling sufficiently tight that it cannot be loosened by the application of a manual wrench alone.

Sec. 1.3—Supplementary Details to Be Specified by Purchaser

When purchasing pipe under this standard, the purchaser shall provide specific supplementary information in his specifications regarding the following details:

1.3.1. Outside diameter.

1.3.2. Wall thickness.

1.3.3. Grade or class designation.

1.3.4. Minimum mill hydrostatic test pressure.

1.3.5. Type of field joints (description or drawings).

1.3.6. Lengths—that is, whether single random (average length 17½ ft), double random (average length 35 ft), or specified cut length (see Sec. 7.4.1 for percentage of minimum and maximum lengths).

1.3.7. The maximum number of longitudinal and girth seams permitted in each length.

1.3.8. All special sections and special fittings, indicating, for each component part, the dimensions and type of field joint together with length tolerances.

1.3.9. Whether a certified statement from the contractor that the required inspection and tests have been made is desired.

1.3.10. Any exceptions to variations from this standard for special requirements for further processing.

Sec. 1.4—Inspection

1.4.1. All work done and material furnished under this standard may be inspected by the purchaser, but such inspection shall not relieve the manufacturer of his responsibility to furnish material and perform work in accordance with this standard. If the inspector desires to inspect the pipe or witness the tests, reasonable notice shall be given of the time at which the inspection is to be made. When requested by the purchaser, a certified statement from the manufacturer that the required inspection and tests have been made shall be furnished.

1.4.2. At all times while work on the contract is being performed the inspector shall have free entry to all parts of the manufacturer's works which concern the manufacture of the pipe ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the pipe is being manufactured in accordance with this standard. All inspections shall be made at the place of manufacture prior to shipment and shall be so conducted as not to interfere unnecessarily with the operation of the works.

1.4.3. The inspector may reject any or all pipe sections or special sections that do not conform to the prescribed test results, conditions of pipe, and tolerances set forth in this standard, the approved drawings, and in the purchaser's supplementary specifications.

Sec. 1.5—Workmanship

1.5.1. *Defects.* The finished pipe shall be free from injurious defects. Defects in seamless pipe or in the parent metal of welded pipe shall be considered injurious when the depth of defect is greater than 12.5 per cent of the tabulated wall thickness. All cracks, sweats, and leaks in welds shall be considered injurious. All end welding of longitudinal seams of fusion-welded pipe, if not done by automatic submerged-arc or automatic shielded-arc welding, shall be done by a procedure and a welder qualified in accordance with Sec. 6.

1.5.2. *Repair of defects.* The repair of injurious defects shall be permitted at the discretion of the manufacturer, except that the repair of defects in seamless pipe or in the parent metal of welded pipe shall not be permitted if the depth of defect exceeds one-third of the tabulated wall thickness of the pipe and the length of that portion of the defect in which the depth exceeds 12.5 per cent is greater than 25 per cent of the tabulated outside diameter of the pipe, or if more than one repair is required in any length equivalent to ten times the tabulated outside diameter of the pipe. Repairs shall conform to the following requirements:

a. The defect shall be completely removed and the cavity thoroughly cleaned.

b. The repair weld shall be made by either automatic or manual welding, by a procedure and a welder qualified in accordance with Sec. 6.

c. Each length of repaired pipe shall be tested hydrostatically in accordance with Sec. 4.1.

Section 2—Chemical Properties and Tests

Sec. 2.1—Chemical Properties

The steel furnished for pipe under this standard shall be of good welding quality and shall conform to the chemical requirements shown in Table 1 for the grade of pipe ordered. Steel may be made by any of the following processes, in accordance with the method of pipe manufacture: open hearth, electric furnace, basic oxygen, killed deoxidized acid, or basic bessemer.

Sec. 2.2—Tests

2.2.1. *Ladle analysis.* When requested by the purchaser, the manufacturer shall furnish a report giving the ladle analysis of each heat of open-hearth, electric-furnace, or basic-oxygen

steel and such analyses as the manufacturer may customarily make of bessemer steel used in the manufacture of pipe conforming to this standard. The analyses so determined shall conform to the requirements specified in Table 1.

2.2.2. *Check analysis.* When so specified on the purchase order, the manufacturer shall furnish a report of check analysis on finished pipe $2\frac{3}{8}$ in. and larger. The number of samples for check analysis shall be one from each of two lengths of pipe from each lot of 400 lengths or fewer of each size $2\frac{3}{8}$ in. through $5\frac{9}{16}$ in., one from each of two lengths from each lot of 200 lengths or fewer of each size $6\frac{5}{8}$ in. through 20 in., and one from each of two lengths from each lot of 100 lengths or fewer of each size 22 in. and larger. For multiple-length pipe, a length shall be considered as all of the sections cut from a particular multiple length. The samples shall be taken as follows:

TABLE 1

Chemical Requirements for Ladle Analysis

Type of Steel	Maximum Content—*per cent*		
	Manganese	Phosphorus	Sulfur
Furnace butt welded	0.65	0.11	0.06
Grade A	1.25	0.04	0.05
Grade B	1.25	0.11	0.05
Grade X42	1.25	0.10	0.05

a. Seamless pipe. At the option of the manufacturer, cuttings or drillings for check analysis shall be taken either from tensile test specimens or from the pipe at several points around the finished pipe. If drillings are used, the minimum drill size shall be $\frac{1}{2}$ in. and drillings shall be taken by drilling all the way through the pipe wall.

b. Welded pipe. At the option of the manufacturer, cuttings or drillings for check analysis shall be taken from the finished pipe, plate, skelp, tensile-test specimens, or flattening-test specimens. The location of the samples shall be approximately 90 deg from the weld. Samples shall be taken in such a manner as to represent the total wall thickness. The minimum drill size shall be $\frac{1}{2}$ in. The composition so determined shall conform to the ladle analysis limits, and permissible variations shall not exceed the following amounts: manganese, +0.05 per cent; phosphorus, +0.01 per cent; sulfur, +0.01 per cent.

2.2.3. *Recheck analysis.* If the check analysis of both lengths of pipe representing the lot fails to conform to the specified requirements, at the manufacturer's option, either the lot shall stand rejected or all the remaining lengths in the lot shall be tested individually for conformance to the specified requirements. If only one of the two samples fails, at the manufacturer's option, either the lot shall stand rejected or two recheck analyses shall be made on two additional lengths from the same lot. If both recheck analyses conform to the requirements, the lot shall be accepted except for the length represented by the initial analysis which failed. If one or both of the recheck analyses fail, at the manufacturer's option, the entire lot shall be rejected or each of the remaining lengths shall be tested individually. In the individual testing of the remaining lengths in any lot, analysis for only the disqualifying element or elements need be determined. Samples for recheck analysis shall be taken in the same manner as specified for check analysis samples.

Section 3—Mechanical Properties and Tests

Sec. 3.1—Mechanical Properties

Pipe furnished under this standard shall conform to the tensile properties specified in Table 2 for the particular grade ordered. The yield strength shall be the tensile stress required to produce a total elongation, under load, of 0.5 per cent of the gage length, as determined by an extensometer or by multiplying dividers. Minimum elongation requirements for seamless and electrically welded pipe shall be those in Table 3 for the particular grade ordered. If the tabulated wall thickness of seamless or electrically welded pipe is other than those listed in Table 3 or less than 0.312 in., the minimum elongation requirement shall be determined by one of the following formulas:

Grade	Formula
A	$E = 56t + 17.50$
B	$E = 48t + 15.00$
X42	$E = 40t + 12.50$

in which E is the minimum elongation in 2 in. (in per cent) and t is the tabulated wall thickness (in inches). Minimum elongation and gage length requirements for furnace-butt-welded pipe 1.050 in OD and smaller shall be those set forth in Table 4.

TABLE 2

Minimum Tensile Requirements for Mill-Type Steel Water Pipe

Type of Steel	Tensile Strength *psi*	Yield Point *psi*
Furnace butt welded	45,000	25,000
A	48,000	30,000
B	60,000	35,000
X42	60,000	42,000

TABLE 3

Minimum Elongation Requirements for Seamless and Electrically Welded Mill-Type Steel Water Pipe

Tabulated Wall Thickness *in.*	Grade A	Grade B	Grade X42
	Elongation in 2 in.—*per cent*		
0.312 and larger	35.00	30.00	25.00
0.281	33.25	28.50	23.75
0.250	31.50	27.00	22.50
0.219	29.75	25.50	21.25
0.188	28.00	24.00	20.00
0.156	26.25	22.50	
0.124	24.50	21.00	
0.094	22.75	19.50	
0.062	21.00	18.00	

Sec. 3.2—Tensile Tests

For seamless and furnace-butt-welded pipe in all sizes and for electric-welded pipe 6⅝ in. and smaller, the tensile properties shall be determined by tests on longitudinal specimens conforming to the requirements of Sec. 3.2.1. For electric-welded pipe 8⅝ in. and larger, the tensile-test specimens may be taken transversely; specimens shall conform to the requirements of Sec. 3.2.2. Tensile tests on all longitudinal specimens and on all transverse body test specimens shall include yield strength, tensile strength, and elongation determinations. At the option of the manufacturer, transverse yield strength may be determined by the ring expansion method. Transverse weld test specimens need be tested for tensile strength only. All tensile tests shall be made with the specimens at room temperature.

3.2.1. *Longitudinal tensile-test specimens.* Longitudinal tensile-test speci-

mens shall be either full-section specimens or strip specimens, at the option of the manufacturer. Strip specimens from seamless pipe may be taken from any location, at the option of the manufacturer. Strip specimens shall be taken approximately 90 deg from the weld or, at the option of the manufacturer, from the skelp, parallel to the direction of rolling and approximately midway between the edge and the center. All longitudinal strip specimens shall be approximately 1½ in. wide in the gage length if suitable curved-face testing grips are at hand; otherwise, they shall be approximately ¾ in. wide for pipe 3½ in. and smaller, approximately 1 in. wide for pipe 4 in. through 6⅝ in., and approximately 1½ in. wide for pipe 8⅝ in. and larger. Longitudinal test specimens shall represent the full wall thickness of the pipe from which the specimens were cut and shall be tested without flattening.

3.2.2. *Transverse tensile-test specimens.* Transverse body test specimens from electric-welded pipe shall be taken opposite the weld; transverse weld test specimens shall be taken with the weld at the center of the specimen. All transverse test specimens shall be approximately 1½ in. wide in the gage length, and shall represent the full wall thickness of the pipe from which the specimens were cut.

3.2.3. *Number of tensile tests required.* One tensile test shall be made on one length of pipe from each lot of 400 lengths or fewer of each size 6 in. and smaller, from each lot of 200 lengths or fewer of each size 6⅝ in. through 20 in. and from each lot of 100 lengths or fewer of each size 22 in. and larger. For multiple-length pipe, a length shall be considered as all of the sections cut from a particular multiple length. For electric-welded pipe, one transverse tensile test shall be made of the weld on a length of pipe from each lot of 200 lengths or fewer of each size 8⅝ in. through 12¾ in. and from each lot of 100 lengths or fewer of each size 14 in. and larger.

3.2.4. *Retest.* If the tensile-test specimen representing a lot of pipe fails to conform to the specified requirements, the manufacturer may elect to make restests on two additional lengths from the same lot. If both of the retest specimens conform to the requirements, all the lengths in the lot shall be accepted except the length from which the initial specimen was taken. If one or both of the retest specimens fail to conform to the specified requirements, the manufacturer may elect to test individually the remaining lengths in the lot, in which case, determinations are required only for the particular requirements with which the specimens failed to comply in the preceding tests. Specimens for retests shall be taken in the same manner as specified in Sec. 3.2.1 and Sec. 3.2.2. If any tensile-test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted. When the elon-

TABLE 4

Minium Elongation and Gage Length Requirements for Furnace-Butt-Welded Pipe 1.050 in. OD and Smaller

Outside Diameter *in.*	Nominal Size *in.*	Gage Length *in.*	Elongation in 8 in. *per cent*
1.050	¾	6	18
0.840	½	6	18
0.675	⅜	4	18
0.540	¼	4	18
0.405	⅛	2	18

gation of any tensile-test specimen is less than that specified, if any part of the fracture is outside of the middle third of the gage length as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

Sec. 3.3—Flattening Tests

3.3.1. *Nonexpanded electric-welded* pipe. For nonexpanded electric-welded pipe (except automatic-fusion-welded pipe) produced in single lengths, the crop ends cut from each length shall be flattened between parallel plates, with the weld at the point of maximum bending, until opposite

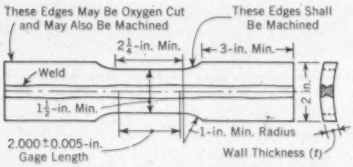

Fig. 1. Tensile-Elongation Test Specimen

The weld reinforcement shall be removed from both faces of the specimen.

walls of the pipe meet. No opening in the weld shall appear until the distance between the plates is less than two-thirds of the original outside diameter of the pipe, and no cracks or breaks in the metal shall occur elsewhere than in the weld until the distance between the plates is less than one-third of the original outside diameter of the pipe. Also, evidence of laminations or burned metal shall not develop during the entire flattening operation. If any crop end fails to conform to these requirements, additional tests shall be made on specimens cut from the same end of the same length of pipe until the requirements are met, except that the finished pipe shall not be shorter than 80 per cent of its length after the initial cropping. Precautions shall be taken that crop ends can be identified with respect to the length of pipe from which they were cut.

3.3.2. *Nonexpanded resistance-welded pipe.* For nonexpanded resistance-welded pipe produced in multiple lengths and subsequently cut into single lengths, a flattening test shall be made as described in Sec. 3.3.1 above on test specimens cut from each end of each coil. If one or both of the specimens fail to conform to the requirements, the manufacturer may elect to make retests on specimens cut from each end of each individual length.

3.3.3. *Cold-expanded electric-welded pipe.* For cold-expanded electric-welded pipe (except automatic fusion-welded pipe), a flattening test shall be made as described in Sec. 3.3.1 above on a ring 4 in. or wider cut from one end of a length of pipe from each lot of 100 lengths or fewer of each size. If the specimen fails to conform to the requirements, the manufacturer may elect to make retests on specimens cut from one end of two additional lengths from the same lot. If both retest specimens conform to the specified requirements, all the lengths in the lot shall be accepted except the length from which the initial specimen was taken. If one or both of the retest specimens fail to conform to the specified requirements, the manufacturer may elect to repeat the test on specimens cut from one end of the individual lengths remaining in the lot.

3.3.4. *Butt-welded pipe 2⅞ in. and larger.* For butt-welded pipe 2⅞ in. and larger, one section of pipe approxi-

mately 6 in. long, cut from a length from each lot of 400 lengths or fewer, of each size, shall be flattened between parallel plates with the weld located approximately 45 deg from the point of maximum bending. No cracks shall occur in any portion of the pipe, and no opening shall occur in the weld until the distance between the plates is less than 60 per cent of the original outside diameter of the pipe. If the specimen fails to conform to these requirements, the manufacturer may elect to make retests on specimens cut from two additional lengths from the same lot. If all retest specimens conform to the specified requirements, all the lengths in the lot shall be accepted except the length from which the initial specimen was taken. If one or more of the retest specimens fail to conform to the specified requirements, the manufacturer may elect to repeat the test on specimens cut from the individual lengths remaining in the lot.

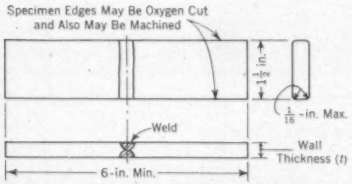

Fig. 2. Guided-Bend Test Specimen

The weld reinforcement shall be removed from both faces of the specimen.

Sec. 3.4—Bend Tests for Butt-Welded Pipe

For butt-welded pipe 2⅜ in. and smaller, one full-section specimen of appropriate length, cut from a length of pipe from each lot of 400 lengths or fewer of each size, shall be bent cold through 90 deg around a mandrel having a diameter not greater than twelve times the outside diameter of the pipe being tested, with the weld located approximately 45 deg from the point of contact of the specimen with the mandrel. No cracks shall occur in any portion of the pipe, and no opening shall occur in the weld. If the specimen fails to conform to these requirements, the manufacturer may elect to make retests on specimens cut from two additional lengths from the same lot. If all retest specimens conform to the specified requirements, all the lengths in the lot shall be accepted except the length from which the initial specimen was taken. If one or more of the retest specimens fail to conform to the specified requirements, the manufacturer may elect to repeat the test on specimens cut from the individual lengths remaining in the lot.

Sec. 3.5—Fusion Weld Tests

For fusion-welded pipe, the weld shall be tested by either of the tests described below, at the option of the manufacturer. The required specimens shall be cut from a length of pipe from each lot of 100 lengths or less of each size. The specimens shall not contain any repair welding made by the manual metallic-arc procedure.

3.5.1. *Tensile-elongation test.* One specimen conforming to Fig. 1 shall be tested in tension, and shall conform to the elongation requirements specified in Table 2.

3.5.2. *Guided-bend test.* One face bend specimen conforming to Fig. 2 shall be bent approximately 180 deg in a jig substantially in accordance with Fig. 3. The specimen shall not fracture completely, and no cracks ex-

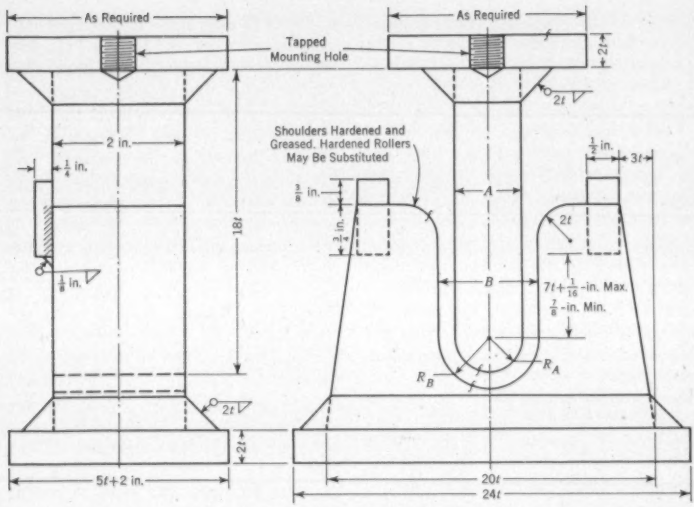

Fig. 3. Jig for Guided-Bend Test

The symbol "f" indicates a light finish cut; t *is the tabulated wall thickness of the pipe. For pipe of Grade A or B, the dimensions* A *and* B *shall be* 4t *and* 6t + ⅛ *in., respectively; for pipe of Grade X42, these dimensions shall be* 6t *and* 8t + ⅛ *in., respectively* ($R_A = \frac{1}{2}$ A *and* $R_B = \frac{1}{2}$ B).

ceeding ⅛ in. in any direction shall be present in the weld metal or between the weld metal and pipe metal. Cracks which originate at the edges of the specimen and which are less than ¼ in. long shall not be cause for rejection.

3.5.3. *Retests.* If the tensile-elongation specimen or the guided-bend specimen fails to conform to the specified requirements, the manufacturer may elect to repeat the test on specimens cut from two additional lengths of pipe from the same lot. If such specimens conform to the specified requirements, all the lengths in the lot shall be accepted, except the length initially selected for the test. If any of the retest specimens fails to pass the specified requirements, the manufacturer may elect to test specimens cut from the individual lengths remaining in the lot. Specimens for retests shall be taken in the same manner as specified in Sec. 3.5.1 and Sec. 3.5.2.

TABLE 5

Dimensions, Weights, and Test Pressures for Mill-Type Steel Water Pipe

Nominal Size *in.*	Outside Diam. *in.*	Inside Diam. *in.*	Weight per Linear Foot* *lb*	Wall Thickness *in.*		Butt Welded	Grade A	Grade B
				Decimal	Fraction	Test Pressure—*psi*		
$\frac{1}{8}$	0.405	0.269	0.24†	0.068	$\frac{1}{16}$	700	700	700
$\frac{1}{4}$	0.540	0.364	0.42†	0.088		700	700	700
$\frac{3}{8}$	0.675	0.493	0.57†	0.091	$\frac{3}{32}$	700	700	700
$\frac{1}{2}$	0.840	0.622	0.85†	0.109	$\frac{7}{64}$	700	700	700
$\frac{3}{4}$	1.050	0.824	1.13†	0.113		700	700	700
1	1.315	1.049	1.68†	0.133		700	700	700
$1\frac{1}{4}$	1.660	1.380	2.27†	0.140	$\frac{9}{64}$	800	1,000	1,100
$1\frac{1}{2}$	1.900	1.610	2.72†	0.145		800	1,000	1,100
2	2.375	2.067	3.65†	0.154	$\frac{5}{32}$	800	1,000	1,100
$2\frac{1}{2}$	2.875	2.469	5.79†	0.203	$\frac{13}{64}$	800	1,000	1,100
3	3.500	3.068	7.58†	0.216	$\frac{7}{32}$	800	1,000	1,100
3	3.500	3.250	4.51	0.125	$\frac{1}{8}$		1,300	1,500
		3.188	5.58	0.156	$\frac{5}{32}$		1,600	1,900
		3.124	6.63	0.188	$\frac{3}{16}$		1,900	2,200
		3.068	7.58	0.216	$\frac{7}{32}$		2,200	2,500
		3.000	8.68	0.250	$\frac{1}{4}$		2,500	2,500
		2.938	9.67	0.281	$\frac{9}{32}$		2,500	2,500
$3\frac{1}{2}$	4.000	3.750	5.17	0.125	$\frac{1}{8}$		1,100	1,300
		3.688	6.41	0.156	$\frac{5}{32}$		1,400	1,600
		3.624	7.63	0.188	$\frac{3}{16}$		1,700	2,000
		3.548	9.11†	0.226		1,200	2,000	2,400
		3.500	10.01	0.250	$\frac{1}{4}$		2,200	2,500
		3.438	11.17	0.281	$\frac{9}{32}$		2,500	2,500
4	4.500	4.250	5.84	0.125	$\frac{1}{8}$		1,000	1,200
		4.188	7.25	0.156	$\frac{5}{32}$		1,200	1,500
		4.124	8.64	0.188	$\frac{3}{16}$		1,500	1,800
		4.062	10.00	0.219	$\frac{7}{32}$		1,700	2,000
		4.026	10.79†	0.237	$\frac{15}{64}$	1,200	1,900	2,200
		4.000	11.35	0.250	$\frac{1}{4}$		2,000	2,300
		3.938	12.67	0.281	$\frac{9}{32}$		2,200	2,500
		3.876	13.98	0.312	$\frac{5}{16}$		2,500	2,500
5	5.563	5.251	9.02	0.156	$\frac{5}{32}$		1,000	1,200
		5.187	10.76	0.188	$\frac{3}{16}$		1,200	1,400
		5.125	12.49	0.219	$\frac{7}{32}$		1,400	1,700
		5.047	14.62†	0.258			1,700	1,900
		5.001	15.87	0.281	$\frac{9}{32}$		1,800	2,100
		4.939	17.52	0.312	$\frac{5}{16}$		2,000	2,400
		4.875	19.16	0.344	$\frac{11}{32}$		2,200	2,500

* Plain end.
† Standard weight.

TABLE 5—*Physical Data for Mill-Type Pipe (contd.)*

Nominal Size *in.*	Outside Diam. *in.*	Inside Diam. *in.*	Weight per Linear Foot* *lb*	Wall Thickness *in.*		Grade A	Grade B
				Decimal	Fractional	Test Pressure—*psi*	
6	6.625	6.249	12.89	0.188	3/16	1,000	1,200
		6.187	14.97	0.219	7/32	1,200	1,400
		6.125	17.02	0.250	1/4	1,400	1,600
		6.065	18.97†	0.280	9/32	1,500	1,800
		6.001	21.07	0.312	5/16	1,700	2,000
		5.937	23.06	0.344	11/32	1,900	2,200
		5.875	25.03	0.375	3/8	2,000	2,400
8	8.625	8.249	16.90	0.188	3/16	800	900
		8.187	19.64	0.219	7/32	900	1,100
		8.125	22.36	0.250	1/4	1,000	1,200
		8.071	24.70†	0.277		1,200	1,300
		8.001	27.74	0.312	5/16	1,300	1,500
		7.981	28.55†	0.322	21/64	1,300	1,600
		7.937	30.40	0.344	11/32	1,400	1,700
		7.875	33.04	0.375	3/8	1,600	1,800
		7.749	38.26	0.438	7/16	1,800	2,100
10	10.750	10.374	21.15	0.188	3/16	650	750
		10.312	24.60	0.219	7/32	750	850
		10.250	28.04	0.250	1/4	850	1,000
		10.192	31.20†	0.279	9/32	1,000	1,200
		10.136	34.24†	0.307		1,000	1,200
		10.062	38.20	0.344	11/32	1,100	1,300
		10.020	40.48†	0.365		1,200	1,400
		9.874	48.19	0.438	7/16	1,500	1,700
12	12.750	12.312	29.28	0.219	7/32	600	700
		12.250	33.38	0.250	1/4	700	800
		12.188	37.45	0.281	9/32	800	950
		12.126	41.51	0.312	5/16	900	1,000
		12.090	43.77†	0.330		1,000	1,200
		12.062	45.55	0.344	11/32	1,000	1,200
		12.000	49.56†	0.375	3/8	1,100	1,200
		11.938	53.56	0.406	13/32	1,100	1,300
		11.874	57.53	0.438	7/16	1,200	1,400
14	14.000	13.500	36.71	0.250	1/4	650	750
		13.438	41.21	0.281	9/32	700	850
		13.376	45.68	0.312	5/16	800	950
		13.312	50.14	0.344	11/32	900	1,000
		13.250	54.57†	0.375	3/8	950	1,100
		13.124	63.37	0.438	7/16	1,100	1,300
		13.000	72.09	0.500	1/2	1,300	1,500
16	16.000	15.500	42.05	0.250	1/4	550	650
		15.438	47.22	0.281	9/32	650	750
		15.376	52.36	0.312	5/16	700	800
		15.312	57.48	0.344	11/32	750	900
		15.250	62.58†	0.375	3/8	850	1,000
		15.124	72.72	0.438	7/16	1,000	1,100
		15.000	82.77	0.500	1/2	1,100	1,300

* Plain end.
† Standard weight.

TABLE 5—*Physical Data for Mill-Type Pipe (contd.)*

Nominal Size *in.*	Outside Diam. *in.*	Inside Diam. *in.*	Weight per Linear Foot* *lb*	Wall Thickness *in.*		Grade A	Grade B	Grade X42
				Decimal	Fractional	Test Pressure—*psi*		
18	18.000	17.500	47.39	0.250	1/4	500	600	
		17.438	53.22	0.281	9/32	550	650	
		17.376	59.03	0.312	5/16	600	750	
		17.312	64.82	0.344	11/32	700	800	
		17.250	70.59†	0.375	3/8	750	900	
		17.124	82.06	0.438	7/16	900	1,000	
		17.000	93.45	0.500	1/2	1,000	1,200	
20	20.000	19.500	52.73	0.250	1/4	450	500	
		19.438	59.23	0.281	9/32	500	600	
		19.376	65.71	0.312	5/16	550	650	
		19.312	72.16	0.344	11/32	600	700	
		19.250	78.60†	0.375	3/8	700	800	
		19.124	91.41	0.438	7/16	800	900	
		19.000	104.13	0.500	1/2	900	1,000	
22	22.000	21.376	72.38	0.312	5/16	500	600	
		21.312	79.51	0.344	11/32	550	650	
		21.250	86.61	0.375	3/8	600	700	
		21.124	100.75	0.438	7/16	700	850	
		21.000	114.81	0.500	1/2	800	950	
24	24.000	23.500	63.41	0.250	1/4	400	450	790
		23.438	71.25	0.281	9/32	400	500	890
		23.376	79.06	0.312	5/16	450	550	990
		23.312	86.85	0.344	11/32	500	600	1,090
		23.250	94.62	0.375	3/8	550	650	1,190
		23.188	102.37	0.406	13/32	600	700	1,280
		23.124	110.10	0.438	7/16	650	750	1,380
		23.000	125.49	0.500	1/2	750	850	1,580
26	26.000	25.500	68.75	0.250	1/4			730
		25.438	77.25	0.281	9/32			820
		25.376	85.73	0.312	5/16			910
		25.312	94.19	0.344	11/32			1,010
		25.250	102.63	0.375	3/8			1,100
		25.188	111.05	0.406	13/32			1,190
		25.124	119.44	0.438	7/16			1,280
		25.062	127.82	0.469	15/32			1,370
		25.000	136.17	0.500	1/2			1,460
28	28.000	27.500	74.09	0.250	1/4			680
		27.438	83.26	0.281	9/32			760
		27.376	92.41	0.312	5/16			850
		27.312	101.53	0.344	11/32			930
		27.250	110.64	0.375	3/8			1,020
		27.188	119.72	0.406	13/32			1,100
		27.124	128.79	0.438	7/16			1,190
		27.062	137.83	0.469	15/32			1,270
		27.000	146.85	0.500	1/2			1,360

* Plain end.
† Standard weight.

TABLE 5—*Physical Data for Mill-Type Pipe (contd.)*

Nominal Size *in.*	Outside Diam. *in.*	Inside Diam. *in.*	Weight per Linear Foot* *lb*	Wall Thickness *in.*		Grade X42
				Decimal	Fractional	Test Pressure *psi*
30	30.000	29.500	79.43	0.250	1/4	630
		29.438	89.27	0.281	9/32	710
		29.376	99.08	0.312	5/16	790
		29.312	108.88	0.344	11/32	870
		29.250	118.65	0.375	3/8	950
		29.188	128.40	0.406	13/32	1,030
		29.124	138.13	0.438	7/16	1,110
		29.062	147.84	0.469	15/32	1,190
		29.000	157.53	0.500	1/2	1,270
32	32.000	31.500	84.77	0.250	1/4	600
		31.438	95.28	0.281	9/32	670
		31.376	105.76	0.312	5/16	740
		31.312	116.22	0.344	11/32	820
		31.250	126.66	0.375	3/8	890
		31.188	137.08	0.406	13/32	960
		31.124	147.48	0.438	7/16	1,040
		31.062	157.86	0.469	15/32	1,110
		31.000	168.21	0.500	1/2	1,190
34	34.000	33.500	90.11	0.250	1/4	560
		33.438	101.28	0.281	9/32	630
		33.376	112.43	0.312	5/16	700
		33.312	123.56	0.344	11/32	770
		33.250	134.67	0.375	3/8	840
		33.188	145.76	0.406	13/32	910
		33.124	156.82	0.438	7/16	980
		33.062	167.87	0.469	15/32	1,050
		33.000	178.89	0.500	1/2	1,120
36	36.000	35.500	95.45	0.250	1/4	530
		35.438	107.29	0.281	9/32	600
		35.376	119.11	0.312	5/16	660
		35.312	130.90	0.344	11/32	730
		35.250	142.68	0.375	3/8	790
		35.188	154.43	0.406	13/32	860
		35.124	166.17	0.438	7/16	930
		35.062	177.88	0.469	15/32	990
		35.000	189.57	0.500	1/2	1,060

* Plain end.

Section 4—Hydrostatic Tests

Sec. 4.1—Mill Inspection Hydrostatic Test

Each length of pipe shall withstand, without leakage, a mill inspection hydrostatic test to at least the pressure shown in Table 5. Sizes larger than shown in Table 5 shall be tested to at least the pressure specified by the purchaser. Test pressures for all sizes of seamless pipe and for welded pipe in sizes 18 in. and smaller shall be held for not less than 5 sec. Test pressures for welded pipe in sizes 20 in. and larger shall be held for not less than 10 sec. For threaded-and-coupled pipe, the test shall be applied with the couplings made handling-tight, or made up power-tight if power-tight makeup is specified on the purchase order, except that 20-in. pipe and larger may be tested in the plain-end condition.

Sec. 4.2—Special Sections

4.2.1. Special sections and fittings made from pipe manufactured to this standard need not be hydrostatically tested.

4.2.2. All special sections and fittings not made from pipe manufactured to this standard shall be subjected to a hydrostatic test at a pressure * specified by the purchaser.

Section 5—Circumferential Welding of Straight Pipe Lengths

Sec. 5.1—Method

Welding of any type generally recognized as sound commercial practice shall be permitted.

Sec. 5.2—Workmanship

5.2.1. The ends of the pipe to be welded together shall be prepared in accordance with the requirements of the process used. The completed length shall be straight, within limits specified in this standard.

5.2.2. The weld shall have a substantially uniform cross section throughout the circumference of the pipe. The crowned surface shall at no point be below the outside surface of the parent metal, nor shall the crown at any point rise above the outside surface of the pipe more than $\frac{1}{8}$ in. Finished lengths of mill pipe, when so stipulated, shall permit the passage of a drift $\frac{1}{8}$ in. less than the nominal inside diameter of the pipe for sizes up to but not including $8\frac{5}{8}$ in.; $\frac{5}{32}$ in. on sizes $8\frac{5}{8}$–14 in.; and $\frac{3}{16}$ in. on sizes 16–20 in.

Section 6—Manual Metallic-Arc Repair Welding

Sec. 6.1—Procedure

All manual metallic-arc repair welds shall be made according to a tested procedure and by a repair welder qualified in accordance with Sec. 6.2 and Sec. 6.3, except that, at the option of the manufacturer, the test specified in the latest edition of the following publications may be substituted: API 1104 (Standard for Field Welding of Pipelines), ASA B31.1 (American Standard Code for Pressure Piping, Sec. 6), and ASME Boiler and Pres-

* The hydrostatic test pressures are mill inspection test pressures. They are not intended as a basis for design, and do not necessarily have any direct relationship to working pressures.

sure Vessel Code, Sec. IX. Test welds may be made either on plate stock or on pipe stock at the option of the manufacturer. The manufacturer shall maintain a record of the procedure and performance test results.

Sec. 6.2—Procedure Tests

Manual metallic-arc repair welding procedure tests shall be required on two specimens of every grade and on material at least as thick as the pipe on which repair welds are to be made. The transverse butt weld tensile test and either the longitudinal weld tensile-elongation test or the transverse guided weld bend test shall be made, except that the manufacturer shall have the option set forth in Sec. 6.1 above.

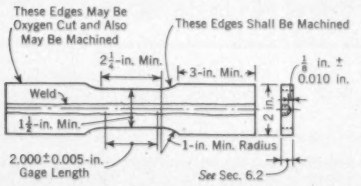

Fig. 4. Tensile-Elongation Test Specimen

The weld reinforcement shall be removed.

6.2.1. *Transverse butt-weld tensile test.* The transverse butt-weld tensile test specimen shall be approximately 1½ in. wide and shall have the transverse manual metallic-arc butt weld perpendicular to the longitudinal axis at the center of the test specimen. The weld reinforcement shall be removed from both faces. The ultimate tensile strength shall be at least equal to the minimum specified for the grade.

6.2.2. *Longitudinal-weld tensile-elongation test.* The longitudinal-weld tensile-elongation test specimen shall conform to Fig. 4. The weld shall be made in a groove as shown. The elongation after complete rupture of the test specimen in tension shall be at least equal to the minimum elongation specified for the grade.

6.2.3. *Transverse guided weld bend test.* The transverse guided weld bend test specimen shall conform to Fig. 5. The weld shall be made in a groove as shown. Specimens shall be bent approximately 180 deg in a jig substantially in accordance with Fig. 3 with the exposed surface of the weld in tension. The bend test shall be acceptable if no crack or other defect exceeding ⅛ in. in any direction is present in the weld metal or between the weld and the pipe metal after bending. Cracks which originate along the edges of the specimen during testing and which are less than ¼ in. measured in any direction shall not be considered detrimental.

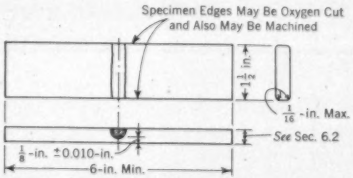

Fig. 5. Guided-Bend Test Specimen

The weld reinforcement shall be removed.

Sec. 6.3—Repair Welder's Performance Tests

Manual metallic-arc repair welder's performance tests shall be required on two specimens of every grade. If either of the two specimens fails to conform to the requirements specified, four retests shall be required immediately or two retests shall be required if the welder takes further instruction

in the practice before making a retest. All retests shall conform to the requirements specified. Further performance tests are not required unless the repair welder has not engaged in the tested repair welding procedure for a period of 3 months or more, or unless there is some specific reason to question his ability. Either of the following tests shall be made: the longitudinal weld tensile-elongation test (described in Sec. 6.2.2, above) or the transverse guided-weld bend test (described in Sec. 6.2.3, above).

Section 7—Tolerances

Sec. 7.1—Diameter

The outside diameter of pipe 1.900 in. and smaller shall not be more than 0.016 in. larger or 0.031 in. smaller than the specified outside diameter. The outside diameter of pipe larger than 1.900 in. shall not vary from the specified outside diameter by more than 1.0 per cent. Pipe $10\frac{3}{4}$ in. and smaller shall not be more than $\frac{1}{64}$ in. smaller than the tabulated outside diameter for a distance of 4 in. from the end of the pipe and shall permit the passage over the ends, for a distance of 4 in., of a ring gage which has a bore $\frac{1}{16}$ in. larger than the tabulated outside diameter of the pipe. Pipe $12\frac{3}{4}$–20 in. shall not be more than $\frac{1}{32}$ in. smaller than the tabulated outside diameter for a distance of 4 in. from the end of the pipe and shall permit the passage over the ends, for a distance of 4 in., of a ring gage which has a bore $\frac{3}{32}$ in. larger than the tabulated outside diameter of the pipe. At the option of the manufacturer, the minimum outside diameter of pipe in sizes 20 in. and smaller may be based on circumferential measurements. Pipe 22 in. and larger shall not be more than $\frac{1}{32}$ in. smaller nor more than $\frac{3}{32}$ in. larger than the tabulated outside diameter for a distance of 4 in. from the end of the pipe, based on circumferential measurements.

Sec. 7.2—Wall Thickness

For pipe in sizes 18 in. and smaller, the wall thickness shall not be more than 15.0 per cent greater than or 12.5 per cent less than the specified thickness. For pipe in sizes 20 in. and larger the wall thickness shall not be more than 15.0 per cent greater than or 10.0 per cent less than the specified thickness.

Sec. 7.3—Weight

The weight per foot of single lengths of pipe of all sizes in a regular-weight series shall not be more than 10.0 per cent greater than or 3.5 per cent less than the specified weight. The weight of carload lots of pipe in all sizes shall not be more than 1.75 per cent less than the specified weight.

Sec. 7.4—Length

7.4.1. *Straight pipe sections.* For all classes of pipe, when ordered to a specified length, the actual length shall not vary from the specified length by more than $\frac{1}{8}$ in. Unless otherwise agreed upon between the purchaser and the manufacturer, pipe shall be furnished in single random lengths or double random lengths as specified on the purchase order. If single random lengths are specified, the average length shall not be less than $17\frac{1}{2}$ ft, and no

piece shall be shorter than 9 ft. If double random lengths are specified, the average length shall not be less than 35 ft, not more than 10 per cent of the lengths shall be shorter than 26½ ft, and no piece shall be shorter than 14 ft. If the average length agreed upon is in excess of 20 ft, not more than 10 per cent of the lengths shall be shorter than 75 per cent of the average length agreed upon, and no length shall be shorter than 40 per cent of the average length agreed upon.

7.4.2. *Special sections.* For special sections, such as elbows, wyes, tees, reducers, and closure pieces, the length tolerance shall be that shown in the drawings.

Sec. 7.5—Straightness

Finished pipe shall be reasonably straight for the application of interior lining.

Section 8—Pipe Ends

Sec. 8.1—Ends for Mechanical Couplings

8.1.1. Plain ends for use with mechanical couplings shall be square cut or beveled and the inside and outside edge burrs shall be removed. The pipe shall be sufficiently free from indentations, projections, or roll marks at each end to make a tight joint.

8.1.2. Ends for other types of mechanical couplings shall have tolerances within the limits required by the manufacturer of the coupling to be used.

Sec. 8.2—Ends for Field Butt Welding

8.2.1. For pipe of wall thickness ¼ in. or greater for field butt welding, the ends shall be beveled on the outside, on the inside, or from both sides, as specified, to an angle of 30 deg, with a maximum plus tolerance of 5 deg and no minus tolerance. It shall be understood that the angle of the bevel is measured from a line drawn perpendicular to the axis of the pipe. The width of the root face at the end of the pipe shall be $\frac{1}{16}$ in. with a tolerance of $\frac{1}{32}$ in.

8.2.2. For pipe of wall thickness less than ¼ in. for field butt welding, the ends need not be beveled.

Sec. 8.3—Bell-and-Spigot Ends With Rubber Gasket

For bell-and-spigot ends for use with a rubber gasket, the difference in measurement between the outside circumference of the spigot and the inside circumference of the bell shall be no less than 0.060 in. and no greater than 0.200 in.

Sec. 8.4—Threaded Ends

Threaded ends shall conform to the threading requirements specified in Sec. IX of API 5L. One end of each length of threaded pipe shall be provided with a coupling, and the other end with thread protection, both conforming to the requirements of Sec. VIII of API 5L. Couplings shall be screwed to the pipe handling-tight except that they shall be applied power-tight if so specified on the purchase order. A high-grade thread compound shall be applied to cover the full surface of either the coupling or pipe-engaged thread before making up the joint. All exposed threads shall be coated with a high-grade thread compound unless otherwise specified on the purchase order.

Sec. 8.5—Ends for Other Types of Joints

Ends for types of joints not covered above shall be made in accordance with the approved drawings. The other types of ends that may be used are: ends with slip joints (lap joints) for field welding, ends fitted with butt straps for field welding, ends for riveted field joints, bell-and-spigot ends for calked joints, plain ends fitted with flanges, and tapered ends for driven field joints.

Section 9—Marking and Delivery

Sec. 9.1—Marking

Each length of pipe shall be legibly marked by paint stenciling, die stamping, or hot-roll marking to show the manufacturer's name or mark, size of pipe, weight per foot, and grade (whether A, B, or X42).

Sec. 9.2—Delivery

Subject to agreement between the purchaser and the manufacturer, pipe sections shall be delivered in the order quired and shall be loaded in accordance with specifications set forth by the purchaser.

2P-25C-12/60

AWWA C700-61T

American Water Works Association

New England Water Works Association

TENTATIVE

AWWA STANDARD

for

COLD-WATER METERS—DISPLACEMENT TYPE

This "Standard for Cold-Water Meters—Displacement Type" is based upon the best known experience and is intended for use under normal conditions. It is not designed for unqualified use under all conditions, and the advisability of its use for any installation must be subjected to review by the engineer responsible for the installation in the particular locality concerned.

First Edition approved as "Standard" May 10, 1946; Second Edition approved as "Tentative" Jan. 23, 1961.

AMERICAN WATER WORKS ASSOCIATION
Incorporated
2 Park Avenue, New York 16, N.Y.

Tentative AWWA Standard for

Cold-Water Meters—Displacement Type

Sec. 1—Scope

This standard covers the various types and classes of cold-water displacement meters for water works service and the materials and workmanship employed in their fabrication. The displacement meters covered, known as nutating- or oscillating-piston or -disc meters, are practically positive in action, and the pistons or discs displace or carry over a fixed quantity of water for each nutation or oscillation when operated under positive pressure.

Sec. 2—Information to Be Supplied by Purchaser

When placing orders for meters manufactured to conform to this standard, it will be necessary for the purchaser to supply specific supplementary information regarding the following:

2.1. Designation of AWWA C700 used.

2.2. Affidavit of compliance (Sec. 3) and certificate of testing for accuracy and capacity (see Note 3.1) if either will be required.

2.3. Size of meter (Sec. 4.2) and quantity required.

2.4. Whether $\frac{5}{8}$, $\frac{3}{4}$, or 1 in. meters are to be furnished with coupling nuts and tailpieces (Sec. 8.2 and 8.3).

2.5. Whether $1\frac{1}{2}$ and 2 in. meters are to be furnished with flanged ends or threaded ends (Sec. 9.1 and 9.2).

2.6. Whether flanged meters are to be furnished with companion flanges, gaskets, bolts, and nuts (Sec. 9.3 and 10.2).

2.7. Whether meters with nutating or oscillating type of piston or disc are to be furnished (Sec. 1).

2.8. Whether meters are to be furnished with a set of replaceable change gears (see Note 3.3).

2.9. Whether meters are to be of the split-case or frostproof type (Sec. 5.2).

2.10. Type of corrosion protection, if any, required for cast-iron bottom caps (See Sec. 6 and 18).

2.11. Type of register to be furnished—that is, round or straight reading, in US gallons or cubic feet (Sec. 11), and with or without test sweep hand (Sec. 11).

2.12. Whether the serial number of the meter shall be imprinted on the case (Sec. 5.4) as well as on the register box lid (Sec. 12).

2.13. Whether the main casing, register box rings, and covers for 3 in. meters and larger are to be made of copper alloys or of cast iron treated for corrosion resistance (Sec. 18.1 and 18.2).

2.14. If operating water temperatures are to exceed 80°F, permissible modifications of test specifications (Sec. 19 and Note 5.2).

2.15. If water is highly aggressive, whether special materials are required to resist corrosion (see Note 5.3).

Sec. 3—Affidavit of Compliance

The purchaser may require an affidavit from the manufacturer or vendor that the meters furnished under the purchaser's order comply with all applicable requirements of this standard.

Sec. 4—Capacity, Size, and Length

4.1. *Capacity.* Capacity or delivery and pressure loss limits for meters supplied under this standard shall be those shown in Table 1.

4.2. *Size.* The sizes of meters (Table 1) shall be in terms of the nominal size of opening in the inlet and outlet spuds or flanges.

4.3. *Length.* The lengths of meters (Table 2) shall be the overall length from face to face of the inlet and outlet meter spuds or flanges.

Sec. 5—Cases

5.1. All meters shall have an outer case with a separate measuring chamber in which the piston operates. Castings shall not be repaired in any manner. The inlet and outlet spuds or flanges shall be 180 deg apart and located in the same horizontal plane.

5.2. Casings shall be of either split-case or frost protection design, as designated by the purchaser.

5.3. The size, model, and direction of flow through the meter shall be cast, in raised characters, on the outer case of all meters.

5.4. The manufacturer's meter serial number, if required by the purchaser, shall be imprinted on the outer case.

5.5. Meters larger than 1 in. shall be so designed that all interior parts

TABLE 1

Capacity, Pressure Loss, Test Flow, and Piston Speed Limits for Positive Displacement Meters

Meter Size *in.*	Max. Capacity or Delivery Classification *gpm*	Max. Pressure Loss at Max. Capacity *psi*	Min. Test Flow *gpm*	Normal Test Flow Limits *gpm*	Max. No. of Piston Nutations or Oscillations	
					per 10 gal	per cu ft
⅝	20	15	¼	1– 20	580	435
¾	30	15	½	2– 30	333	250
1	50	15	¾	3– 50	153	115
1½	100	20	1½	5– 100	67	50
2	160	20	2	8– 160	40	30
3	300	20	4	16– 300	20	15
4	500	20	7	28– 500	9.3	7
6	1,000	20	12	48–1,000	4	3

may be removed without disturbing the connections to the pipeline.

Sec. 6—Frost Protection Devices

Frost protection devices, when provided, shall be of such design that they will yield or break under normal freezing conditions to minimize damage to any other part of the meter. The internal portion of bottom caps designed to afford frost protection may be protected against corrosion by an inner liner or coating.

Sec. 7—External Case Screws, Bolts, Nuts, and Washers

All external case screws, bolts, cap bolts, nuts, and washers shall be designed for easy removal after long service.

Sec. 8—Connections for $\frac{5}{8}$-, $\frac{3}{4}$-, and 1-in. Meters

8.1. *Main-case connections.* Main-case connections of all $\frac{5}{8}$-, $\frac{3}{4}$-, and 1-in. meters shall be meter casing spuds having external straight threads conforming to the American Standard pipe threads (ASA B2.1), as far as the specifications apply. Pitch diameters shall be those shown in Table 2. When a $\frac{5}{8}$-in. meter is furnished with connections for $\frac{3}{4}$-in. pipe, the spud dimensions shall be as shown for the $\frac{5}{8}\times\frac{3}{4}$-in. size.

TABLE 2

Dimensional Design Limits for Meters, External Connections, and Companion Flanges

Meter Lengths and Connections

Meter Size *in.*	Meter Length—*in.*		Meter Casing Spuds			Coupling Nuts		Couplings and Tailpieces	
	Screw Ends	Flange Ends	Nominal Thread Size *in.*	Min. Pitch	Max. Diameter *in.*	Min. Pitch	Max. Diameter *in.*	Length *in.*	Threads *in.*
$\frac{5}{8}$	$7\frac{1}{2}$		$\frac{3}{4}$	0.978	0.988	0.992	1.002	$2\frac{3}{8}$	$\frac{1}{2}$
$\frac{5}{8}\times\frac{3}{4}$	$7\frac{1}{2}$		1	1.227	1.237	1.242	1.252	$2\frac{1}{2}$	$\frac{3}{4}$
$\frac{3}{4}$	9		1	1.227	1.237	1.242	1.252	$2\frac{1}{2}$	$\frac{3}{4}$
1	$10\frac{3}{4}$		$1\frac{1}{4}$	1.563	1.573	1.580	1.590	$2\frac{5}{8}$	1
$1\frac{1}{2}$	$12\frac{3}{8}$	13							
2	$15\frac{1}{4}$	17							
3		24							
4		29							
6		$36\frac{1}{2}$							

Companion Flange Dimensions

Meter Size *in.*	Min. Thickness at Bolt Hole *in.*	Diameter of Bolt Circle *in.*	No. of Bolt Holes	Diameter of Bolt Holes *in.*	Thickness at Hub *in.*
$1\frac{1}{2}$	$\frac{9}{16}$	4	2	$\frac{11}{16}$*	$\frac{13}{16}$
2	$\frac{5}{8}$	$4\frac{1}{2}$	2	$\frac{11}{16}$*	$\frac{7}{8}$
3	$\frac{3}{4}$	6	4	$\frac{3}{4}$	$1\frac{3}{16}$
4	$\frac{15}{16}$	$7\frac{1}{2}$	8	$\frac{3}{4}$	$1\frac{5}{16}$
6	1	$9\frac{1}{2}$	8	$\frac{7}{8}$	$1\frac{9}{16}$

* Minimum.

8.2. *Coupling nuts.* Coupling nuts shall be tapped American Standard internal straight pipe threads (ASA B2.1), as far as the specifications apply. Pitch diameters shall be those shown in Table 2.

8.3. *Coupling tailpieces.* Coupling tailpieces shall be threaded to conform to American Standard external taper pipe threads (ASA B2.1) and have nominal internal diameter equal to the size of meter openings. Lengths and thread sizes shall be those shown in Table 2.

Sec. 9—Connections for 1½- and 2-in. Meters

Main-case connections for 1½-in. and 2-in. meters may be either spuds on both ends or flanges on both ends.

9.1. *Meter spuds.* Meter spuds shall be tapped 1½ in. and 2 in. respectively American Standard internal taper pipe threads (ASA B2.1).

9.2. *Flanged casings.* Meter casing flanged connections shall be faced and drilled and shall be of the oval type. The drilling shall be on the horizontal axis; the number of bolt holes; the diameter of the bolt holes and bolt circle shall be as shown for companion flanges in Table 2.

9.3. *Companion flanges.* Oval companion flanges, gaskets, bolts, and nuts shall be provided if specified by the purchaser. Companion flanges shall be faced, drilled, and tapped, 1½ in. and 2 in. respectively, American Standard internal taper pipe threads (ASA B2.1). Dimensions shall be those shown in Table 2.

Sec. 10—Connections for 3-, 4-, and 6-in. Meters

10.1. *Meter case connections.* All meter case connections for 3-, 4-, and 6-in. meters shall be flanged. The flanges shall be of the round type, faced and drilled, and shall conform to the American Standard cast-iron pipe flange, class 125 (ASA B16.1) as to diameter and drilling as shown for companion flanges in Table 2.

10.2. *Companion flanges.* Companion flanges, gaskets, bolts, and nuts shall be provided if specified by the purchaser. Companion flanges shall be faced, drilled, and tapped 3 in., 4 in., or 6 in. respectively, American Standard internal taper pipe threads (ASA B2.1) and conform to American Standard cast-iron pipe flange, Class 125 (ASA B16.1) as to diameter, drilling and thickness, all as shown in Table 2.

Sec. 11—Registers

Registers shall be round-reading or straight-reading, subject to the limitation set forth in Sec. 11.3, below, and shall read in US gallons or in cubic feet, as specified by the purchaser. They shall not be in fluid contact with the water being measured.

11.1. *Round-reading registers.* The register pinion and spur gears shall be firmly fastened on their spindles, shall mesh fully with each other and run freely, and shall be so constructed that they cannot become unmeshed. The spindle bearings in the top and bottom register plates shall be bushed. These bushings shall have sufficient depth to insure ample spindle bearing and sufficient clearance to allow the spindles to revolve freely, shall be so fitted that they will not work loose, and shall be removable.

11.1.1. If the register is sealed and thereby not subject to normal corrosion, gears and pinions may run free on fixed shafts or be fixed on shafts that run free in upper and lower plates,

or both, and shall be so constructed that they cannot become unmeshed.

11.1.2. The maximum indications of the initial dial and the minimum capacity of the register shall be those given in Table 3.

TABLE 3

Maximum Indication on Initial Dial and Minimum Register Capacity

Meter Size *in.*	Maximum Indication of Initial Dial		Minimum Capacity of Register	
	cu ft	*gal*	*mil cu ft*	*mil gal*
⅝	1	10	0.1	1
¾	1	10	1	10
1	10	100	1	10
1½	10	100	10	100
2	10	100	10	100
3	10	100	10	100
4	100	1,000	100	1,000
6	100	1,000	100	1,000

11.1.3. All the index circles, including the initial circle, shall be subdivided into ten equal parts. All hands or pointers shall taper to a point and shall be accurately set and securely held in place. Registers may have a center-sweep test hand with the index circle near the periphery of the register face graduated in 100 equal parts, each tenth numbered. The quantities indicated by a single revolution of the test hand shall be those given in Table 3.

11.2. *Straight-reading registers.* The numerals on the number wheels of straight-reading registers shall be large and distinct and easy to read. The register lock and side gears shall be securely fastened to their number wheel discs and hubs. The tumbler pinions shall mesh accurately at the turnover points with the lock and side gears of the adjacent number wheels. Both main and pinion shafts shall be so secured in the register frame that they cannot get out of position. The pinion shaft shall be so designed that there is no possibility of its bending and allowing the pinion to skip at the turnover point.

11.2.1. If the register is sealed and thereby not subject to normal corrosion, gears and pinions may run free on fixed shafts or be fixed on shafts that run free in upper and lower plates, or both, and shall be so constructed that they cannot become unmeshed. The tumbler pinion shall mesh accurately at turnover points with the lock and side gears of adjacent number wheels. Pinions may operate between number wheels mounted in partition plates.

11.2.2. The maximum indication of the digits appearing on the first number wheel and the minimum capacity of the register, shall be those given in Table 3.

11.2.3. The register face shall have a test index circle which shall be divided into ten equal parts. The hand or pointer shall taper to a sharp point and shall be accurately set and securely held in place.

11.2.4. Registers may have a center-sweep test hand with an index circle located near the periphery of the register face and graduated in 100 equal parts, each tenth numbered. The hand or pointer shall taper to a point and shall be accurately set and securely held in place. The quantities indicated by a single revolution of the test hand shall be those shown in Table 3.

11.3. *AWWA standard straight-reading register.* Any new model of meter, as distinguished from modification of existing models, supplied under this standard and first offered for sale

after the date of publication of this standard shall be equipped with AWWA standard straight-reading registers. The register face shall be of the center-sweep test hand type with an index circle located near the periphery of the register face and graduated in 100 equal parts, each tenth numbered. Register construction shall conform, in all other details, to Sec. 11.2 above.

Sec. 12—Register Boxes

The name of the manufacturer shall be cast in raised letters on the lid of all register boxes. The serial number of the meter shall be imprinted on the lid. The lid shall be recessed and shall overlap the register box to protect the glass. The glass shall be securely held in place. All register box compartments of meters having a stuffing box exposed to the atmosphere shall be provided with a drain hole $\frac{1}{8}$ in. in diameter.

Sec. 13—Intermediate Gear Trains

Intermediate gear trains may be mounted on the measuring chamber, in the upper main casing, or, when not exposed to water, combined with or adjacent to the register gearing. Gear trains exposed to water shall be of the oil-enclosed type, shall have a separate housing or form a housing with the main casing or measuring chamber, and shall operate in a suitable lubricant.

Sec. 14—Measuring Chambers

Measuring chambers shall not be cast as part of the outer casings. They shall be machined carefully and secured in position in the outer casings so that any distortion of the casings that might occur at an internal pressure of 150 psi will not affect the sensitivity or registration of the meters.

Sec. 15—Pistons or Discs

Pistons or discs shall be smoothly machined, shall be fitted accurately in their measuring chambers, and shall operate smoothly and freely. The plates of disc pistons, whether flat or conical, shall either be reinforced or equipped with thrust rollers. Disc pistons may be in one piece or composed of a piston plate and two half-balls. The piston spindles or shafts shall be securely fastened in the pistons. The piston or disc nutations or oscillations shall not exceed the quantities given in Table 1.

Sec. 16—Strainers

All meters shall either be provided with strainers or be self-straining by means of an annular space between the measuring chamber and the external case. Strainer screens shall be installed in the meter; they shall be rigid, fit snugly, be easy to remove, and have an effective straining area at least twice that of the main-case inlet.

Sec. 17—Seal Wire Holes

Register box screws, and inlet and outlet coupling nuts, if furnished, shall be drilled for seal wire holes. Seal wire holes shall be not less than $\frac{3}{32}$ in. in diameter.

Sec. 18—Materials *

18.1. *Pressure castings* (*main casings*). On meters in sizes up to and including 2 in., main casings shall be made of a copper alloy containing not

* The composition of all alloys in this section is subject to commercially accepted tolerances.

less than 75 per cent copper. On meters larger than 2 in., main casings shall either be of a copper alloy containing not less than 75 per cent copper or of cast iron protected by a corrosion-resistant coating or other anticorrosion treatment.

18.2. *Register box rings and covers.* On meters in sizes up to and including 2 in., register box rings and covers shall be made of a copper alloy containing not less than 75 per cent copper. On meters larger than 2 in., register box rings and covers shall be either of a copper alloy containing not less than 75 per cent copper or of cast iron.

18.3. *Measuring chambers.* Measuring chambers shall be made of a copper alloy containing not less than 85 per cent copper and suitable amounts of tin, lead, and zinc.

18.4. *Measuring pistons or discs.* Measuring pistons or discs shall be made of vulcanized hard rubber having sufficient rigidity and strength to operate at the rated capacity of the meter. They shall have sufficient dimensional stability to retain operating clearance at working temperatures up to 80°F and shall not warp or deform when exposed to a temperature of 100°F.

18.5. *Measuring chamber diaphragms.** Measuring chamber diaphragms shall be made of monel, phosphor bronze, stainless steel, or hard rubber.

18.6. *Piston spindles, thust rollers, and thrust roller bearing plates.** Piston spindles, thrust rollers, and thrust roller bearing plates shall be made of monel, phosphor bronze, stainless steel, or hard rubber.

18.7. *Intermediate gear trains.* Frames and gears of intermediate gear trains shall be made of a copper alloy containing not less than 75 per cent copper and suitable amounts of tin, lead, and zinc. Pinions shall be made of copper alloy containing not less than 60 per cent copper.

18.8. *Bottoms (breakable).* Breakable bottoms (frost bottoms) shall be made of cast iron or bronze of such design and composition as will satisfy the break or "yield" requirements set forth in Sec. 6.

18.9. *External fasteners (case bolts, nuts, screws, and washers).* All external fasteners for meters in sizes up to 1 in., if the fasteners are cast parts, shall be of the same composition as the meter casing (Sec. 15.1). Fasteners made from rolled mill stock shall be made of copper bearing alloy containing not less than 57 per cent copper or of stainless steel. On meters larger than 1 in., casing bolts, washers, and nuts shall be made of a copper alloy containing not less than 57 per cent copper or of iron or steel treated to resist corrosion.

18.10. *Coupling tubes and nuts.* Coupling tubes and nuts shall be made of a copper alloy containing not less than 57 per cent copper.

18.11. *Companion flanges.* Companion flanges shall be made of cast iron.

Sec. 19—Registration Accuracy

The quantity registered on the meter dial shall be not less than 98.5 per cent and not more than 101.5 per cent of the water actually passed through the meter while the meter is being tested at any rate of flow within the normal test flow limits specified in Table 1 with water at a temperature less than 80°F. Not less than 95 per cent of the actual flow shall be recorded when a test is

* The life of materials used for these meter parts is dependent upon the materials used for other associated parts. The purchaser should not make specific designations without first consulting the manufacturer.

made at the minimum test flow rate set forth in Table 1 with water at a temperature less than 80°F.

Sec. 20—Pressure Requirement

Meters supplied under this standard shall operate without leakage or damage to any part at a working pressure of 150 psi.

Sec. 21—Workmanship and Materials

Meters shall show no defects in materials or workmanship for a period of one year from date of shipment. The manufacturer shall replace, without charge, those parts in which a defect has developed within a year of shipment upon their return to the manufacturer or upon proper proof of a defect, except that this warranty shall not apply if the meter has been modified by the use of replacement parts not made by the manufacturer of the meter.

Sec. 22—Rejected Meters

The manufacturer shall, at his own expense, replace or readjust all meters rejected for failure to comply with this standard.

Notes

The following notes are not to be considered part of AWWA Standard C700. They are given only for purposes of information.

1. Units of Measurement

Approximately half of the water meters in use in the United States register in US gallons and half in cubic feet. This situation makes it extremely difficult to effect standardization. It is recommended, however, that US gallons be acknowledged as the preferable unit of measure and that, whenever possible, US gallons be established as the standard unit.

2. Register Types

Water meter registers may be of the straight-reading or round-reading types. The round-reading type is more often misread, and the problem is further complicated if more than one make of meter is used in a single water system. It is also more difficult to print postcards for customer reading where two or more makes of meters with round-reading registers are used. It is recommended, therefore, that the straight-reading type of register be adopted to eliminate these difficulties.

3. Tests

3.1. *Capacity and pressure loss tests.* Capacity tests are tests of the design of a meter. When a meter of a given design has once been tested for capacity, it should not be necessary to test others of the same type unless a change has been made in design. The capacity test should be made with two identical piezometer rings of the same diameter as the nominal size of the meter being tested. The piezometer rings must be free from any burrs where the holes are drilled through the wall of the ring, and no fewer than four holes should be provided, drilled in pairs on diameters at right angles to each other. The inlet ring should be set close to the meter at a distance of eight diameters or more below the nearest upstream stop valve or fitting, and the outlet ring should be placed 8–10 diameters from the outlet of the meter. The diameter of the inlet and outlet pipe should be the same as the nominal size of the meter to be tested. The rings are to be connected to a mercury U-tube by rubber or metallic tubing, and equipped with an accurate adjustable scale for measuring the difference in mercury level. Provision should be made for the complete removal of air from the U-tube and tubing, and the installation should be such that air will rise to the air outlets. If measurements are to be made at relatively high flow rates, it is necessary to read both sides of the mercury column simultaneously in order to compensate for irregularites in the diameter of the glass U-tube, and to avoid errors due to fluctuations.

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3.2. *Pressure tests.* A pressure test should be made on each size of a particular design of meter furnished. The test pressure should be 150 psi, which may be produced by use of a hand pump or any other available device. The meter should be tested for accuracy before and after it has been pressure tested to determine whether there has been any distortion that could affect the registration. If satisfactory results are obtained, it is unnecessary to make more than one pressure test on each size of a given design of meter.

3.3. *Accuracy tests.* All meters should be tested for accuracy of registration in accordance with AWWA C705, "Recommended Procedure for Testing Cold-Water Meters," which recommends the test flow rates and test flow quantities given in Table A.

If the purchaser does not have suitable means for testing, the manufacturer should be requested to furnish a certificate showing that each meter has been tested for accuracy of registration and that it complies with accuracy and capacity requirements of AWWA C700.

If it is considered necessary by the purchaser to avoid having meters register in excess of 100 per cent *at the maximum rate of flow* during normal periods of service, new meters should be obtained which register not more than 98.5–99 per cent at maximum flow rate when new. This allowance will provide for the slight increase in registration due to the buildup which occurs with most waters. Excessive buildup normally causes friction between the piston and measuring chamber with resultant lowering of accuracy. Registration of displacement type meters is closely controlled by the design and close tolerances of manufacture. Registration increases more than 1.5–2 per cent above the original calibration are rarely experienced.

All meters, until recent years, were equipped with a set of replaceable change gears for effecting changes in registration. Certain types of displacement meters now being produced are not equipped with removable change gears. In such meters, other means for correcting inaccuracy of registration must be utilized.

TABLE A

*Recommended Accuracy Test Flow Rates and Quantities**

Size *in.*	Maximum Rate			Intermediate Rate			Minimum Rate		
	Rate of Flow *gpm*	Test Quantity		Rate of Flow *gpm*	Test Quantity		Rate of Flow *gpm*	Test Quantity	
		gal	*cu ft*		*gal*	*cu ft*		*gal*	*cu ft*
⅝	15	100	10	2	10	1	¼	10	1
¾	25	100	10	3	10	1	½	10	1
1	40	100	10	4	10	1	¾	10	1
1½	80	1,000	100	8	100	10	1½	100	10
2	120	1,000	100	15	100	10	2	100	10
3	250	1,000	100	20	100	10	4	100	10
4	350	1,000	100	40	100	10	7	100	10
6	700	1,000	100	60	100	10	12	100	10

* Registration accuracy limits set forth in Sec. 19, AWWA C700, are 98.5–101.5 per cent for maximum and intermediate rates, and 95 per cent for minimum rates.

4. Testing Equipment

The measuring device used to determine the amount of water discharged in testing should be preferably of volumetric type, designed to provide accuracy of measurement within 0.25 per cent of the actual quantity. Test by weight is satisfactory, however, if the scales are kept accurate.

5. Under- and Overregistration

In a displacement meter, the motion of the piston is transmitted by a system of gearing to the register which records the flow in convenient units of measurement. The

gearing translates the motion of the piston into the unit of measure indicated by the register. The registration is thus directly dependent on the number of nutations or oscillations of the piston. The registration is a true measure of flow only when the meter has been properly calibrated. After proper calibration the meter will continue to register correctly only so long as the piston continues to make the proper number of cycles for each unit of quantity passed through the meter. If any condition should develop whereby the piston is compelled to make fewer than the proper number of cycles per unit of quantity passed through it, the meter will underregister. If the piston is compelled to make more than the proper number of cycles, the meter will overregister. Under ordinary working conditions, a number of factors may cause under- or overregistration after comparatively short intervals. The more important of these are excessive wear, extreme temperatures, corrosion, and material in suspension.

TABLE B

Average Recommended Intervals Between Meter Tests

Meter Sizes in.	Interval Between Tests *years*
$\frac{5}{8}$	10
$\frac{3}{4}$	8
1	6
$1\frac{1}{2}$	4
2	4
3	3
4	2
6	1

5.1. *Excessive wear.* Excessive wear of the moving parts of the meter may be caused by improper setting, by over-speeding, or by the selection of a meter too small for the work required. The effects of excessive wear of the piston or measuring chamber are slippage and underregistration. Excessive wear of the intermediate gear train may cause the gears to slip or to bind. In either case, if the meter does not stop entirely, underregistration will result. To avoid excessive wear, meters should be set in a horizontal position and should not be run at destructive speeds. The capacities given for meters in Table 1 of C700 are the maximum rates of flow at which water should be passed through the meters for short periods of time. They are the peak loads which the meters should undergo only at long intervals and would be destructive if continuous. For continuous 24-hr service, meters of the displacement type should not be operated at flows greater than one-third of their rated capacity.

5.2. *Temperature extremes.* Cold-water meters are not affected by temperatures up to about 80°F. In warm climates, where the temperature of the water is likely to exceed 80°F, meters with slightly larger measuring chamber clearances than usual should be used, and the accuracy limits set forth in Sec. 19 of AWWA C700 must be modified accordingly.

High temperatures can cause expansion of the rubber pistons and create unusual friction or bind the piston in its chamber. The result is slippage and underregistration or complete stoppage of the meter. Low temperatures have no noticeable effect on the working parts of the meter, although freezing will stop the meter and may cause damage.

To avoid troubles caused by temperature extremes, meters should be set at locations where they will be protected from heat and frost. At locations where hot water from heating systems may be forced back through the meter, a check valve and pressure-and-temperature relief valve should be installed on the outlet side of the meter.

5.3. *Corrosion.* All the metals used in the construction of a meter are affected by the corrosive action of water, although the action is very slow with most potable waters.

It should be recognized, however, that when meters are used in highly aggressive waters, it may be necessary to use materials that are more resistant to attack. The solution of the corrosion problem requires a high degree of experience and knowledge, and the manufacturer should be consulted under such circumstances for assistance.

5.4. *Material in suspension.* Foreign material carried in suspension has a tendency to fill the space between the piston and measuring chamber and cause overregistration. Such overregistration is limited, however, and generally cannot exceed 3 per cent.

Meters provided with strainers will retain the larger particles in suspension, but the strainer will soon become clogged if the water is not kept reasonably free from sus-

pended matter. Sand is especially destructive, and care should be exercised to keep sand from reaching the pipes supplying the meter.

6. Periodic Tests

Meters properly selected as to size and type will give satisfactory service over a long period of time without attention only if operated under ideal conditions. Under ordinary conditions, meters must be given some care if they are to function properly. In most cases, it is impossible to ascertain, without actual test, whether a meter in service is registering with the required degree of accuracy. Consequently, to insure reliable meter measurements, it is essential that all meters be subjected to periodic tests. The interval between tests and the method of conducting them must be governed largely by local conditions. Many state regulatory commissions specify intervals between tests on both a time and quantity basis. Under *average* conditions, however, the intervals between tests should not exceed the limits set forth in Table B.

7. Meter Storage

Meters should be stored in a location not subject to unduly high or low temperatures, those with oil-enclosed gear trains should be stored in an inverted position to avoid possible seepage of oil into the measuring chamber.

Prepared by AWWA Committee 8610 D

JAMES G. CARNS JR., *Chairman*

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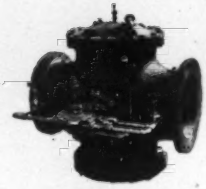

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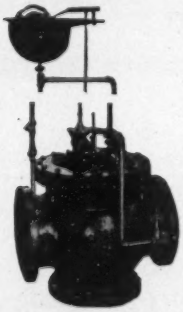

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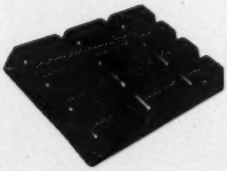

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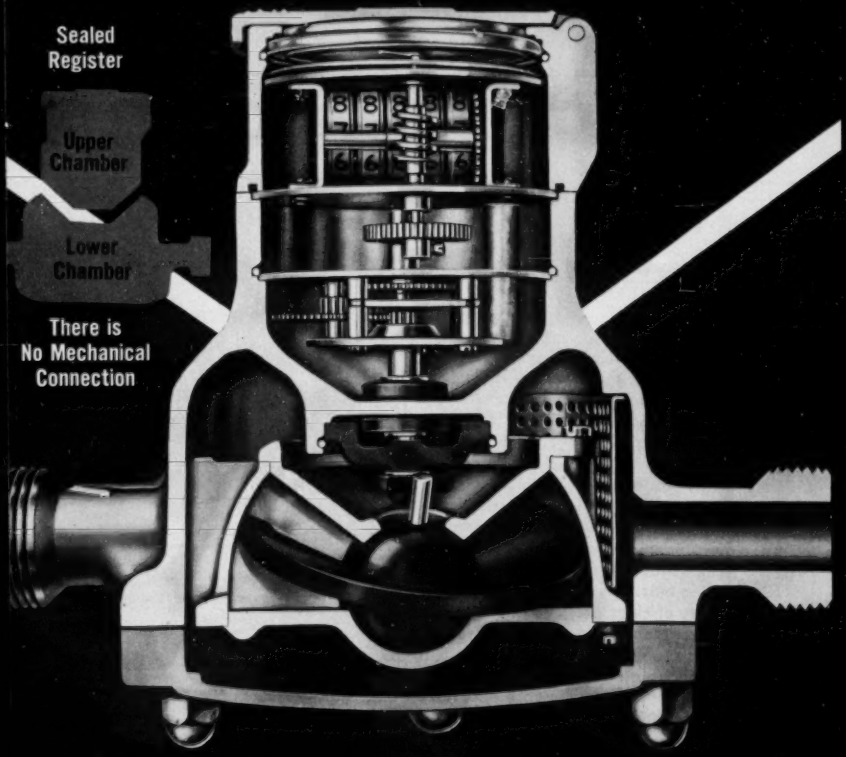

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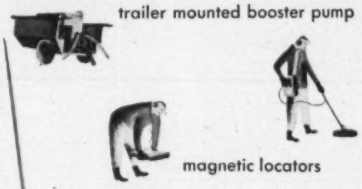

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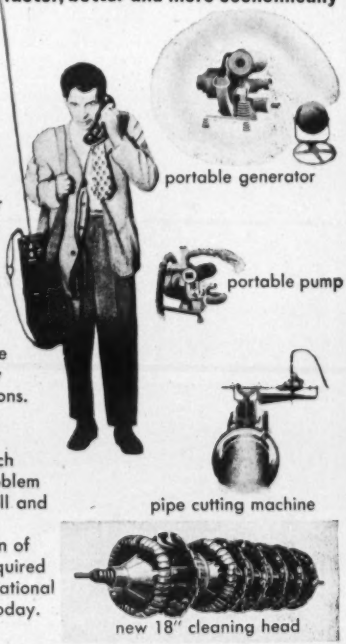

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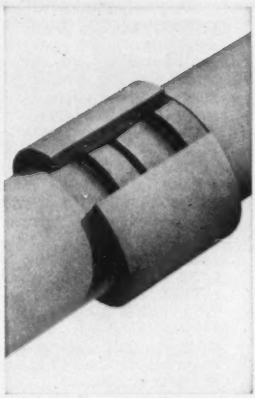

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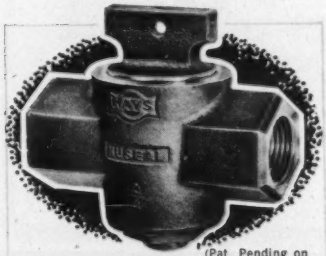

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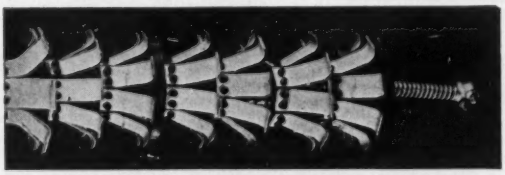

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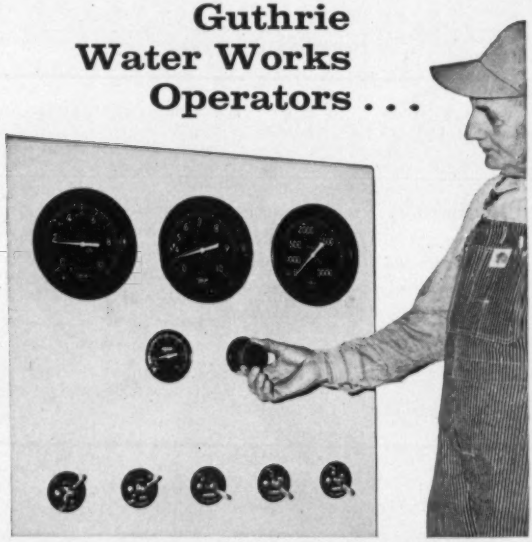

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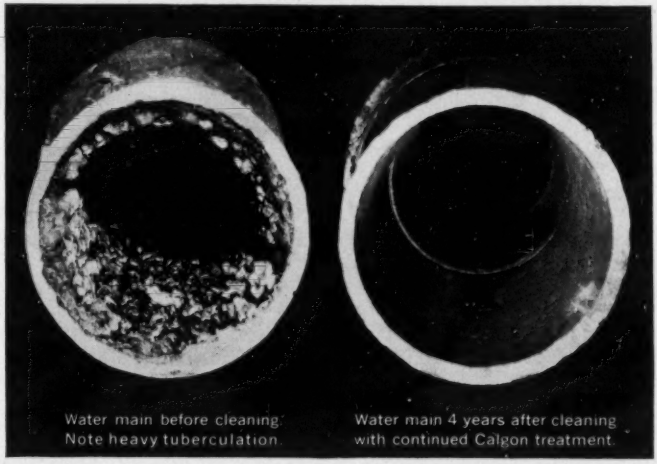

Water main before cleaning. Note heavy tuberculation.

Water main 4 years after cleaning with continued Calgon treatment.

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